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OF SEVERAL WING AND FLAP ARRANGEMENTS

By S. R. Alexander and James C. Sivells

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WASHINGTON

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MEMORANDUM REPORT

for the

Army Air Forces, Air Technical Service Command

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SUMMARY

An investigation was conducted in the Langley 19-foot pressure tunnel to determine the stalling characteristics, aileron effectiveness, and, to a limited extent, the longitudinal stability of a $\frac{1}{14}$-scale model of the XB-36 airplane. The model was tested with the original wing-flap configuration and with several modifications to the outboard panels and flap arrangement. The modifications to the outboard wing panels consisted of (1) the original panels with midchord slots ahead of the ailerons, and (2) a revised panel which incorporated changes in airfoil section, twist, plan form, and aileron area. The flap arrangments included full- and partial-span, single- and double-slotted configurations.

With the original wing and the full-span flap arrangement the model exhibited unsatisfactory stalling characteristics, insufficient aileron effectiveness, particularly with flaps deflected, and longitudinal instability after the stall with flaps deflected. The slotted panels were better than the revised panels in improving the stalling characteristics. None of the configurations tested, however, produced satisfactory stalling characteristics. The configuration with the revised panels exhibited better aileron effectiveness, which is attributed mainly to the increase in aileron area. With flaps deflected, the greatest improvement in aileron effectiveness was realized by changing the flap configuration from full span to

partial span. The use of partial-span, double-slotted
flaps produced a greater maximum lift coefficient than
that obtained with the other flap configurations but caused
a large change in trim lift coefficient. The static longi-
tudinal instability after the stall experienced by the
model with flaps deflected for take-off and landing was
less severe with the modified outboard panels than with
the original wing.

INTRODUCTION

The Consolidated Vultee XB-36 airplane is a proposed
six-engine, pusher-type, long-range bomber. Tests were
conducted on a $\frac{1}{14}$-scale model in the Langley 19-foot
pressure tunnel to determine the stability and control
characteristics of the airplane. In the course of this
investigation, it was found that the stalling character-
istics of the model, in its original configuration, were
unsatisfactory. Besides causing a loss in aileron effec-
tiveness near maximum lift, the stall was also accompanied
by longitudinal instability after maximum lift was reached,
when the flaps were deflected for take-off or landing.
Attempts to rectify these unsatisfactory conditions by the
use of midchord or leading-edge spoiler arrangements proved
inadequate. It was therefore considered inadvisable to
continue with the remainder of the testing schedule until
some practical solution to this problem was secured.

In a further attempt to improve the stalling character-
istics of the airplane, and thereby improve the aileron
effectiveness and longitudinal stability at high lift
coefficients, it was decided to investigate proposed modifi-
cations to the wing and flap arrangement. The manufacturer
proposed to incorporate midchord slots in the wing ahead
of the ailerons. This proposal would entail a minimum
change to the airplane design. The Langley laboratory
proposed to eliminate the outboard flaps, to change the
inboard flaps from single-slotted to double-slotted flaps,
and to revise the outboard wing panels by changing the
airfoil section, twist, plan form, and aileron area.
Although it was realized that the greatest improvement
could be obtained if the entire wing was revised, the
revisions proposed by the Langley laboratory were restricted
to the outboard wing panels (from 62 percent of the semi-
span to the wing tip) to facilitate changes to the airplane

design. These revisions were based upon the theoretical analysis given in the appendix.

Subsequent investigation revealed that, although both proposals produced some improvement, the slotted-panel configuration could be materially improved through elimination of the outboard flaps. Accordingly, this configuration was further investigated with both single- and double-slotted inboard flaps, and, in order to provide comparative data, the NACA panel configuration was also tested with partial-span, single-slotted flaps.

This paper presents the results of stalling, aileron, and some longitudinal stability tests of the original and both modified wing panels, various flap and spoiler arrangements, and full and modified flap-nacelle seals.

COEFFICIENTS AND SYMBOLS

The coefficients and symbols used herein are defined as follows:

C_L lift coefficient, L/qS

C_D drag coefficient, D/qS

C_m pitching-moment coefficient, M/qSc

C_l rolling-moment coefficient, L'/qSb

C_{l_p} rate of change of rolling-moment coefficient with helix angle, $\dfrac{\partial C_l}{\partial \dfrac{pb}{2V}}$

T_c thrust coefficient, $T/\rho V^2 D^2$

L   lift, pounds

D   drag, pounds; diameter of propeller, feet

M   pitching moment, foot-pounds

L'   rolling moment, foot-pounds

T   effective thrust, pounds

q   dynamic pressure of free stream, $\frac{1}{2}\rho V^2$, pounds per
        square foot

S   wing area, square feet

c   mean aerodynamic chord (N.A.C.), feet

b   wing span, feet

pb/2V   helix angle, radians

p   rolling velocity, radians per second

V   airspeed, feet per second

V_i indicated airspeed, miles per hour

V_s indicated airspeed at maximum lift coefficient, miles
        per hour

ρ mass density of air, slugs per cubic foot

α angle of attack of root chord, degrees

δ_{f_i} partial-span, single-slotted inboard-flap deflection,
        degrees

δ_{f_o} partial-span, balanced-split outboard-flap deflection,
        degrees

δ_{f_s} partial-span, double-slotted inboard-flap deflection,
        degrees

δ_a left aileron deflection, positive with trailing edge
        down, degrees

δ_e elevator deflection, positive with trailing edge
        down, degrees

R   test Reynolds number, $\rho Vc/\mu$

M   Mach number, V/V_c

μ coefficient of viscosity, pound seconds per square
        foot

V_c speed of sound in air, feet per second

c_l section lift coefficient

y spanwise location, percent of semispan

W_1 original wing

W_2 wing with slotted outboard panels

W_3 wing with NACA revised outboard panels

MODEL AND TESTS

Model.- The model (fig. 1), with the exception of the wooden empennage and NACA outboard wing panels, was basically of all metal construction. Block inserts containing the slots (figs. 2 and 3) were incorporated in the outboard panels for the W_2 configuration. This outboard panel was replaced by the wooden NACA panel for the tests of W_3. The model was kept smooth by filling surface irregularities with crack filler and glazing putty and, in addition, the wing was sprayed with lacquer and rubbed in a chordwise direction with number 400 carborundum paper to provide an aerodynamically smooth surface.

Protuberances on the fuselage included sighting blisters, antennae for radio-electronic devices, and airspeed pitot-static masts.

A comparison of the physical characteristics of the wing configurations investigated is given in table I and figures 4 and 5.. It should be noted that the additional washout for wing W_3 was obtained by twisting the wing sections about the aileron hinge line..

All the flaps (figs. 5 and 6) were set manually by the use of brackets constructed to give the desired flap deflection. Only the left ailerons, which were of constant chord (figs. 5 and 7), were deflected for the aileron tests. These ailerons were locked manually at the desired deflection and sealed by placing cellulose tape along the gap on both the upper and lower surfaces.

The wing nacelles were constructed with air passages to allow for internal air flow. Duct orifice plates and

plugs at the exits provided means for adjusting the air flow.
Total and static pressure tubes were suitably located in
the left inboard and outboard nacelles for the measurement
of air-flow quantities.

It should be noted that two horizontal tail planes
were installed on the model in the course of the investi-
gation. The original tail, which had an area of 4.95 square
feet and an aspect ratio of 4.49, was used during most of
the stalling and force tests of the original model. The
revised tail, which had an area of 4.99 square feet and
an aspect ratio of 5.50, was used for the remainder of the
tests. The stabilizer was set at -7° to the wing-root
chord.

Tests.- The tests were conducted in the Langley
19-foot pressure tunnel with the air in the tunnel com-
pressed to an absolute pressure of about 35 pounds per
square inch. The model was mounted on the normal three-
support system (fig. 8) and the aerodynamic forces and
moments were measured by means of a six-component, simul-
taneously recording balance system.

With the exception of several stall investigations
made with the model propellers in operation, and force
tests to determine the effect of the spoilers, the tests
presented herein were conducted at a dynamic pressure of
approximately 100 pounds per square foot, with the model
propellers removed. This value of dynamic pressure
corresponds to a Reynolds number of about 4,500,000 and
a Mach number of about 0.17.

Wing W_1 was tested at a Reynolds number of about
2,500,000 with operating propellers. The power conditions
for full-scale operation were simulated in the wind tunnel
by matching the propeller thrust coefficient of the model
with that of the airplane at a given lift coefficient.
The blade angle was 21° at the 0.75 radius station for
all power-on tests. These power ratings were based on
sea-level conditions and on a maximum gross weight of
340,000 pounds.

The nacelle openings were adjusted to give average
values of entrance velocity ratio and flow coefficient of
0.80 and 0.078, respectively. These values were selected
to simulate the nacelle air flow for the full-scale air-
plane when cruising at 30,000 feet. The first tests made

with the partial-span, double-slotted flaps deflected 50°
for landing resulted in a maximum lift coefficient of 1.71.
Comparison with the other model configurations tested made
it apparent that this flap configuration was not an optimum
one. Tests made with the flaps deflected 55° resulted in
lower maximum lift coefficients. Therefore, changes in
flap gap, vane position, and flap position appeared to be
necessary. Because of the model construction, it was not
feasible to change the flap or vane position. Consequently,
in order to decrease the flap gap, the flap-well lip was
extended 0.94 inch   along the wing upper surface as shown
in figure 6. Tests of this arrangement showed satisfactory
increases in maximum lift at the landing-flap deflections.
The 50° flap deflection produced a slightly higher maximum
lift at a higher angle of attack than the 55° flap deflec-
tion. Hence, the 50° flap deflection, with the flap-well
lip extended, was used for all tests presented herein in
which the double-slotted flaps were deflected for landing.

The basic model configurations tested are given in
table II.

RESULTS AND DISCUSSION

The results are presented in the form of standard
nondimensional coefficients. The tare and interference
effects of the model-support struts were not obtained for
all the configurations, and therefore no corrections for
these effects were applied to the lift, drag, and pitching-
moment coefficients. Jet-boundary and air-flow misalinement
corrections were applied to the angle of attack and the
drag coefficient. The rolling-moment coefficients due to
deflection of the left aileron were corrected for jet-
boundary interference and model and tunnel asymmetry.

All coefficients were based on the mean aerodynamic
chord and wing area of the actual wings. All moments were
measured about the quarter-chord point of the mean aero-
dynamic chord of wing W_1 so that the slopes of the
pitching-moment curves would not change for otherwise
similar model configurations.

In the course of the investigation, the original tail
plane was replaced by the revised tail plane. The test
results presented are for the revised tail except where

otherwise noted. A list of the figures presented herein
is given in table III and the results obtained from the
force tests are summarized in table IV. Included in
table IV are values for W_3 based on the wing area of W_1
to facilitate comparison at the same airspeed and airplane
weight. Values of drag coefficient are given for a lift
coefficient of 0.4 (high-speed condition) and 0.8 (cruising
condition).

Stalling Characteristics

The stalling characteristics of the several model
configurations were determined by the observation of tufts
attached to the upper surface of the wing at the 30-, 50-,
70-, and 90-percent wing-chord stations and spaced about
5 inches spanwise. At every angle of attack at which the
flow pattern changed, sketches and moving-picture records
were obtained. All values of lift coefficient presented
on the stall diagrams were obtained with the tufts in
place. The value of the data insofar as the determination
of the stalling characteristics of the wing are concerned
will not be affected by the tail configuration tested.

Wing W_1.- The stalling characteristics observed for
this model configuration with flaps retracted and with
flaps deflected for landing are shown in figure 9. At
the Reynolds number of about 2,500,000 the model propellers
were operated to give zero thrust throughout the lift
range investigated. At the Reynolds number of 5,500,000,
the propellers were removed.

In general, the stall started at the trailing edge
of the wing adjacent to the outboard nacelles and progressed
outboard and forward. The inboard sections partially
stalled, in most cases, after the outboard panels were
completely stalled. The rate of stall progression over
the outer wing panels appeared to be more rapid when the
flaps were deflected. These results indicated unsatis-
factory stall progression which, as will be shown later,
was accompanied by a loss of aileron effectiveness near
maximum lift coefficient, and longitudinal instability
after maximum lift coefficient was reached. The nature
of this stall is such that the pilot may lose control of
the airplane before being adequately warned. The actual
stalling characteristics for flap neutral are in fair
agreement with those predicted by an analysis of the
spanwise section-lift-coefficient distribution (see appendix).

The analysis indicates that the stall at the full-scale Reynolds number would be more severe than that shown by the model tests.

Upon the suggestion of the manufacturer, three spoilers of different vertical heights were tested on the model in an attempt to induce initial stall over the inboard panel at high values of lift coefficient. These spoilers were located on the 40-percent chord line of the wing upper surface and extended from the fuselage to the center line of the center nacelles. The vertical heights of the spoilers were approximately 0.22, 1.0, and 2.0 percent of the wing-root chord, c_R. The 0.22-percent c_R spoiler did not affect the original stall pattern. The 1.0- and 2.0-percent c_R spoilers caused a complete stall behind the spoiler throughout the lift range investigated. It was therefore concluded that, for this model, these spoiler arrangements were unsatisfactory.

In a further attempt to produce better stalling characteristics for the model, tests of a leading-edge spoiler arrangement were included in the investigation. The sharp-nose, leading-edge spoiler was located on the model as shown in figure 10. It was estimated that, for this position, the stagnation point would occur at the sharp edge at zero lift. A similar arrangement with the sharp edge located in such a manner as to coincide with the stagnation point for $c_L = 0.8$ was found to have little effect on the stall progression. In an effort to minimize the effect of the spoiler on the drag of the model, the sharp leading edge was made to include an angle of 90° with sides faired to the wing-section profile.

Diagrams of the stall progression with and without the spoilers and at comparable model configurations are presented in figure 11 for two power conditions. The leading-edge spoiler arrangement did not change the stall pattern at low lift coefficients, but produced intermittent stall at the root sections at higher lift coefficients. A comparison of the spoiler-off data of figure 11 with the data of figure 9(a) indicates that increasing the thrust coefficient tends to clean up the stalled area at the root.

The results of force tests made on the model with propellers removed and with and without the leading-edge

spoiler are presented in figure 12. The spoiler decreased
the maximum lift coefficient 0.12 and 0.04 for the normal
and landing conditions, respectively, but increased the
drag coefficient about, 0.0020 below a lift coefficient of
0.8 for the normal condition. The static longitudinal
instability after maximum lift coefficient, indicated by
the pitching-moment curve of the model, was not as severe
with the spoilers on as with the spoilers off.

This spoiler arrangement was not considered an
acceptable solution to the unsatisfactory stall of the
model inasmuch as the stall progression was not improved.
In addition, the increase in drag, with flaps retracted,
at moderate lift coefficients and the loss in maximum
lift coefficient with flaps retracted and deflected were
deemed prohibitive.

Wing W_2, with full-span flaps.- The stall progression
for this model configuration is presented in figure 13(a).
The stall started at approximately the same place as on
the original wing and gradually progressed inboard. The
midchord slots apparently retarded the stall progression
outboard of the outboard nacelles although the flow over
the ailerons through most of the lift range was very rough.

Wing W_2, with partial-span, single-slotted flaps.-
The stall studies made with this model configuration with
flaps deflected for take-off and landing are presented in
figure 13(b). In general, the stall progression was
similar for both flap conditions. The rough flow over
the ailerons typical of the slotted panels was not affected
by the change in flap configuration.

Wing W_2, with partial-span, double-slotted flaps.-
The stall studies for this model configuration are shown
in figure 13(c). The flap neutral characteristics are
reproduced from figure 13(a). This configuration with
flaps deflected for landing may be worse than the other
flap configurations inasmuch as the stall over the flaps
was decreased, thereby decreasing the chances for a stall
warning for the pilot. On the other hand, the stalled
aileron area at maximum lift was slightly decreased. The
regions of rough flow over the ailerons were not affected
by the change in flap configuration.

Wing W_3.- The stalling characteristics of the NACA
arrangement are shown in figure 14. These panels showed
some improvement over the original panels for the flap-
neutral condition inasmuch as the center sections stalled
before the ailerons completely stalled. The stall over
the ailerons was not delayed as much with these panels as
with the slotted panels. With flaps deflected, the stall
over the ailerons was but slightly delayed by these panels
as compared with the original wing and the stall over the
flaps was eliminated by the action of the double-slotted
flaps.

The improvement in the flap-neutral stalling character-
istics predicted from the analysis presented in the appendix
was only partially realized in the actual case possibly
because of the break in the wing leading edge resulting
from sweeping forward the leading edge of the outboard
panels. As in the case of wing W_1, the analysis indicates
that the stall at the full-scale Reynolds number would be
more severe than that shown by the model tests.

Aileron Characteristics

The lift and rolling-moment characteristics of the
model with the left aileron deflected were determined from
tests made at a Reynolds number of about 4,500,000 with
the model propellers removed. The results of these tests
were used to estimate the aileron rolling effectiveness
of the airplane in terms of the developed helix angle,
$pb/2V$. This helix angle is estimated to be approximately
equal to $\dfrac{0.8C_l}{C_{l_p}}$, where C_{l_p} is dependent upon the aspect
and taper ratios of the wing plan form. The values of C_{l_p}
for both wing plan forms were calculated from lifting-line
theory to which an edge-velocity correction was applied
(method similar to that used in reference 1). These values
were determined to be 0.548 for W_1 and W_2 and 0.563
for W_3. The indicated airspeed was computed for the
normal gross weight of 265,000 pounds, using the untrimmed
lift coefficient obtained with zero elevator deflection.

Wing W_1.- The aileron characteristics for the original
wing with the left aileron deflected over the range, -20°
to 20°, are presented in figure 15. The aileron rolling

effectiveness, calculated in terms of the estimated helix
angle pb/2V for the airplane in the normal and landing
configuration is shown in figure 16. The requirement for
satisfactory aileron effectiveness, pb/2V = 0.07 at
110 percent of the stalling speed, prescribed in reference 2,
will probably not be met by the airplane for any of the
flap configurations tested. A value of pb/2V of 0.07
was obtained at higher speeds with the model equipped with
the partial-span, single-slotted flaps deflected for landing.
It can clearly be seen that the outboard flaps were detri-
mental to the aileron effectiveness, particularly when the
aileron was deflected down. Near the stall, the rolling
moment due to the down aileron became negative. This loss
in effectiveness results from the close proximity of the
down aileron and the deflected flap as shown in figure 6(b).
A value of pb/2V of only 0.031 was obtained at 110 percent
of the stalling speed with the full-span flaps deflected,
while a value of 0.052 was obtained with the partial-span
flaps only. Both of these values were low as a result of
the tip stall experienced with this wing.

Wing W_2.- The aileron characteristics for the model
with the slotted panels are presented in figure 17. These
results are presented for flaps neutral and for the three
types of flaps deflected for landing. The left aileron
was deflected over the range -25° to 20° for the condition
with the partial-span, double-slotted flaps and -20° to 20°
for the flaps neutral, the full-span and the partial-span,
single-slotted flaps. The estimated helix angle for these
flap conditions are presented in figure 18. The addition
of the midchord slots did not appreciably increase the
aileron effectiveness at 110 percent of the stalling speed
even though they did produce an improvement in the stalling
characteristics. The main effect of the slots was to
maintain the rolling effectiveness to lower speeds by
increasing the maximum lift coefficient. The slots, how-
ever, caused loss of aileron rolling effectiveness through-
out most of the climbing to high-speed range and, with
flaps deflected, caused complete loss of effectiveness near
the stalling speed. A large improvement in rolling effec-
tiveness was obtained at low speeds by changing the flap
configuration from full-span to partial-span, thereby
eliminating the interference effects of the outboard flaps
on the flow over the ailerons. The rolling moment due to
the down aileron, however, still became negative near
maximum lift coefficient. An acceptable value of pb/2V
of 0.07 was attained at 110 percent of the stalling speed

with differential aileron deflections of -25° and 20° for
the condition with partial-span, double-slotted flaps. It
should be noted that it will be much more difficult to
balance the aileron at the -25° deflection than at the -20°
deflection because of the rapid, nonlinear increase in
hinge-moment coefficients in this range of aileron deflec-
tions. On the other hand, the -25° deflection may not be
necessary if the aileron area is increased to provide
satisfactory control for the flap-neutral condition.

Wing W_3.- Figures 19 and 20 present the aileron
characteristics and estimated helix angle, respectively,
for the model equipped with the NACA outer panels. With
the differential aileron deflection, the satisfactory
aileron rolling effectiveness requirements are met at
110 percent of the stalling speed and are exceeded for
higher speeds. This configuration, with its increased
aileron area, produced the greatest $pb/2V$ value of any
of the configurations tested. The aileron effectiveness,
furthermore, is maintained beyond the stall, a condition
which was not realized for either the W_1 or W_2 configu-
ration. Again, the aileron balance problem at the -25°
deflection is quite important, although in this case, this
deflection may be decreased a few degrees without decreasing
the helix angle below 0.07. A comparison of the values
of $pb/2V$ at a given indicated airspeed makes the superior
aileron effectiveness of W_3 still more apparent.

Lift, Drag, and Pitching-Moment Characteristics

The lift, drag, and pitching-moment characteristics
of the model with the several wing outer panels and flap
configurations were determined from tests made at a Reynolds
number of approximately 4,500,000. The stabilizer was set
at -7° to the wing-root chord and, with two exceptions in
which the deflection was -10° (figs. 23(b) and 24(b)), the
elevator was set at 0°.

All of these tests were made with the revised hori-
zontal tail plane installed on the model.

Wing W_1.- Some tests were made with fixed transition
to show the effect of surface roughness on drag and longi-
tudinal stability. The transition was fixed (fig. 21) at
11 percent of the wing chord (approximate location of the
front spar on the airplane). The lift, drag, and pitching-

moment characteristics are presented in figure 22. The
fixed transition increased the maximum lift coefficient,
increased the drag below a lift coefficient of 1.1, and
did not affect the pitching moment appreciably. The longi-
tudinal instability at the stall associated with this model-
wing configuration with full-span flaps is apparent from
an examination of the pitching-moment curves of figure 22.
This instability is less severe with the partial-span,
single-slotted flaps and is not indicated with flaps
retracted.

Wing W_2.- The lift, drag, and pitching-moment
characteristics for this model configuration are presented
in figure 23. The addition of the slots increased the
maximum lift coefficient for all three flap deflections
tested. The longitudinal instability at the stall has
been reduced for the take-off and landing configurations.
The slots did not appreciably affect the trimmed lift
coefficient of the model with elevator neutral.

The characteristics of the model with the partial-
span, double-slotted flaps deflected for landing and with
the elevator set at $0°$ and $-10°$ are presented in figure 23(b).
This flap configuration produced a still greater maximum
lift than was obtained with the other flap configurations.
The large change in trim lift coefficient experienced by
the model when the double-slotted flaps were deflected,
however, would probably cause an undesirable control con-
dition. This situation probably resulted from the increased
downwash over the horizontal tail surfaces caused by the
high concentration of lift at the wing center section when
the double-slotted flaps were deflected.

Wing W_3.- The results of tests made on the model to
determine the aerodynamic characteristics of the NACA panels
with partial-span, single- and double-slotted flaps are
presented in figure 24. With the partial-span, single-
slotted flaps deflected for landing, the NACA panels pro-
duced a lower value of maximum lift coefficient than the
W_1 and W_2 configurations. The landing speed of W_3
would, however, be the same as W_1 if no change in weight
were involved because of the greater wing area of W_3.
With flaps neutral and natural transition, the drag
characteristics of this wing are essentially similar to
that of the original and slotted wing panels. The effect
of fixing the transition at 11 percent of the wing chord
for the flaps-retracted condition was, in general, similar

to that for fixed transition on the original panels. The
maximum lift coefficient obtained with the partial-span,
double-slotted flaps deflected for landing was lower for
this wing configuration than for the slotted panels.

        In an attempt to increase further the maximum lift,
full and modified seals between the flaps and nacelles
were added as shown in figure 25. The seals showed a loss
in maximum lift coefficient rather than an improvement
(fig. 26).

        Static longitudinal instability after the stall was
equally present for the W_3 as for the W_2 configuration,
but was not as severe as for the W_1 configuration.

Model Configuration for Further Tests

        At the completion of the tests described herein, the
manufacturer decided to incorporate, in the design of the
first airplane, the configuration with the slotted panels
and the partial-span, single-slotted flaps (the slots in
the panels are intended to be closed when the flaps are
retracted). This decision was made on the basis of the
results of the tests and from a consideration of the
problems involved in the production of the airplane.

        The configuration selected has about the least unsatis-
factory stalling progression of any tested. The elimi-
nation of the outboard flap materially improved the aileron
effectiveness. Some sacrifice in maximum lift coefficient
is involved in this selection since an increase in maximum
lift coefficient could be realized if the double-slotted
flap configuration had been selected.

        On the basis of the manufacturer's decision, the
configuration selected was used for further tests in the
Langley 19-foot pressure tunnel to determine the lateral
and longitudinal stability and control characteristics of
the model.

CONCLUSIONS

        The following conclusions are indicated by tests of
a $\frac{1}{14}$-scale model of the XB-36 airplane with several wing
and flap configurations:

1. The stalling progressions of all configurations
tested are considered to be unsatisfactory. The stall of
the original configuration originates at the outboard
nacelles and progresses gradually outboard enveloping the
tips before the inboard-section stalls. The slotted panels
are more effective than the NACA panels in delaying the
stall over the ailerons. This delay allows the stall to
move inboard, except for the configuration with the double-
slotted flaps deflected where the action of the flaps cleans
up the stall over the center sections. Although the slotted
panels retard the stall over the ailerons, there remains
a considerable amount of rough flow behind the slots.

2. It is estimated that about 86 percent of the
required value of pb/2V (0.07) can be obtained at 110
percent of the stalling speed, with the original configu-
ration with flaps neutral. When the full-span flaps are
deflected, a serious loss in rolling effectiveness is
experienced. The addition of the midchord slots in the
outboard panels does not appreciably increase the aileron
effectiveness at 110 percent of the stalling speed even
though the stall over the outboard panels is delayed. At
speeds higher than 110 percent of the stalling speed, the
slots lower the aileron effectiveness, except for the
condition of full-span flaps deflected. A large increase
in effectiveness, at 110 percent of the stalling speed, is
realized when the flap configuration is changed from full
span to partial span. With differential deflection, -25°
and 20°, of the ailerons, it is estimated that a value of
pb/2V equal to 0.07 can be obtained with the condition
of partial-span, double-slotted flaps deflected and slots
open in the outboard panels. With the NACA outboard panels,
which have greater aileron area, the required value of
pb/2V equal to 0.07 is exceeded with differential aileron
deflection, -25° and 20°, for both the conditions of flaps
neutral and with partial-span, double-slotted flaps deflected
for landing.

3. The greatest maximum lift coefficient is obtained
with the configurations incorporating the slotted panels.
The partial-span, double-slotted flaps produce a greater
increment of maximum lift coefficient than either the full-
span or the single-slotted flap arrangement. There is
little difference between the maximum lift coefficient
obtained with the original panels and that obtained with
the NACA panels. The addition of flap-nacelle seals slightly
decreases the maximum lift coefficient for W_3.

    4. The longitudinal instability at the stall experienced with flaps deflected on the original wing was not as severe for either the slotted or the NACA panels. The partial-span, double-slotted flaps cause a much greater change in trim than either the full-span or the single-slotted flap configuration.

Langley Memorial Aeronautical Laboratory
    National Advisory Committee for Aeronautics
        Langley Field, Va., February 23, 1945

APPENDIX

THEORETICAL ANALYSES FOR WINGS, W_1 AND W_3

The analyses for wings W_1 and W_3 were made for only
the flap-neutral condition because of the inadequacy of
such analyses for flap-deflected conditions. The effects
of fuselage, nacelles, ducts, and the sweepback of the
wings could not be taken into account in the method used
for analysis. It was realized that sweepback might have
an adverse effect on the stalling characteristics but any
improvement gained by altering the wing design should be
apparent whether or not the effect of sweepback is included
in the analyses.

The method of analysis is that described in reference 3.
This method consists essentially of determining the point
at which the curve of the spanwise distribution of the
section lift coefficient becomes tangent to the curve of
the spanwise variation of the maximum lift coefficient of
each section (see figs. 27 and 28). The spanwise location
of the point of tangency represents the point at which
stalling is expected to begin. The margin between the
two curves is an indication of the manner in which the
stall will progress. To avoid tip stalling, it is recom-
mended in reference 4 that there should be a margin of at
least $c_l = 0.1$ at 0.70 of the semispan. The value of the
wing lift coefficient required to make the curves tangent
is the theoretical maximum lift coefficient obtainable.
The maximum lift coefficient of each section was obtained
from section data for the particular Reynolds number and
thickness of each section. The section lift coefficient
was also obtained from section data by means of the method
of computing the span-load distribution described in
reference 5. This method uses actual section data instead
of assuming straight-line lift curves.

The results of the analysis for wing W_1 is shown
in figure 27. For the model Reynolds number of 5,500,000,
the curves indicate that the stall would start from about
0.35 to 0.65 of the semispan and, because of the small
margin at 0.70 of the semispan, would spread rapidly toward
the tip. For the full-scale Reynolds number of 22,000,000
based upon a speed of about 100 miles per hour, the curves

indicate that the stall would start at about 0.90 of the semispan. These analyses indicate that the stalling characteristics of the model as observed in the tunnel would be unsatisfactory even though the stall would start further inboard than on the full-scale airplane due to the difference in Reynolds number. The effects of the jet boundary on the model stalling characteristics were computed and found to be negligible.

The design of wing W_3 was influenced by a number of factors. Although it was realized that the greatest improvement in stalling characteristics would result from a redesign of the entire wing, practical considerations limited the design to the wing panel outboard of a station approximately 62 percent of the semispan. This station is outboard of the outboard nacelle and approximates the line of detachment of the outboard wing panels on both the model and the full-scale airplane. In order to minimize any increase in drag for the new wing panels, the use of fixed slots was not considered, although such use might improve the stalling characteristics. The tip chord was increased by 50 percent to decrease the taper ratio. This increase was distributed on each side of the original plan form in such a manner as to keep the location of the aero-dynamic center of the wing the same as that of the original wing. In order to increase the maximum lift coefficient obtainable at the tip and the angle of attack for this lift coefficient, the tip airfoil section was changed from an NACA 63(420)-517 section to an NACA 65(315)-517 section. As a further prevention against tip stalling, the washout was increased to 3° at approximately the 75-percent semi-span station (location of outboard end of aileron tab) and 4° at the tip. This increase in washout was obtained by twisting the wing panel about the aileron hinge line.

The results of the analysis for wing W_3 is shown in figure 28. For the model Reynolds number of 4,700,000, the curves indicate that the stall would start from 0.30 to 0.50 of the semispan and would be more satisfactory than that of W_1 since it would not tend to spread to the tip. For the full-scale Reynolds number, the curves indicate that the stall would start about 0.60 of the semispan. Again, the Reynolds number effect makes the stalling characteristics of the model somewhat optimistic compared to those of the full-scale airplane.

The analyses for the two wings $(W_1$ and $W_3)$ indicate that the stalling characteristics of W_3 will be better than those of W_1. The stall will probably start further inboard and not spread outboard as fast. Any effect due to sweepback would also favor W_3 since the sweepback of the outboard panel is reduced about $2\frac{1}{2}^{\circ}$. The improvement in stalling characteristics is obtained at an expense of only about $2\frac{1}{2}$-percent increase in induced drag for a cruising condition of 288 miles per hour at 30,000 feet altitude and a gross weight of 265,000 pounds.

No analysis for wing W_2 could be made because of the lack of two-dimensional data applicable to this wing.

REFERENCES

1. Swanson, Robert S., and Toll, Thomas A.: Estimation
       of Stick Forces from Wind-Tunnel Aileron Data. NACA
       ARR No. 3J29, 1943.

2. Anon.: Stability and Control Requirements for Air-
       planes. AAF Specification No. C-1815, Aug. 31, 1943.

3. Anderson, Raymond F.: Determination of the Character-
       istics of Tapered Wings. NACA Rep. No. 572, 1936.

4. Soule, H. A., and Anderson, R. F.: Design Charts
       Relating to the Stalling of Tapered Wings. NACA
       Rep. No. 703, 1940.

5. Boshar, John: The Determination of Span Load Distri-
       bution at High Speeds by Use of High-Speed Wind-
       Tunnel Section Data. NACA ACR No. 4B22, 1944.

TABLE I

FLAP AND AILERON CHARACTERISTICS

Wing	Surface	Type	Symbol for deflection	Chord, percent wing chord mid-span of surface	Span, percent wing semispan	Figure
W_1, W_2, W_3	Inboard flap	Slotted	δ_{f_1}	25	42	5(a) 5(b) & 6(a)
W_1, W_2	Outboard flap	Balanced split	δ_{f_o}	20	38	5(a) & 6(b)
W_2, W_3	Inboard flap	Double slotted	δ_{f_s}	27	42	6
W_1, W_2	Aileron	Sealed	δ_a	15	38	5(a) & 7
W_3	Aileron	Sealed	δ_a	16	43	5(b) & 7

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TABLE II

WING AND FLAP CONFIGURATIONS
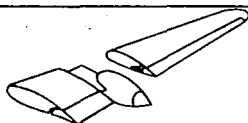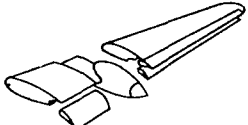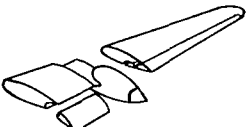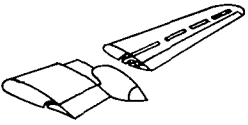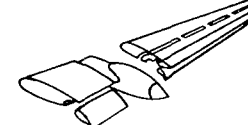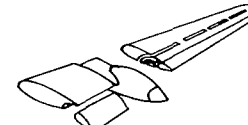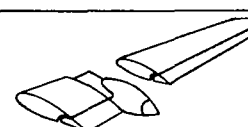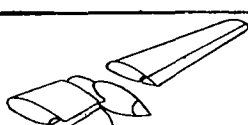
Wing	Symbol	Flap	δ_{f_i} (deg)	δ_{f_o} (deg)	δ_{f_s} (deg)	Flight condition
CVAC original wing	W_1	full-span	0 20 40	0 50 50	----- ----- -----	Normal Take-off Landing
------Do------	W_1	partial-span, single-slotted	40	-----	-----	Landing
Original wing with slotted outer panels	W_2	full-span	0 20 40	0 50 50	----- ----- -----	Normal Take-off Landing
------Do------	W_2	partial-span, single-slotted	20 40	----- -----	----- -----	Take-off Landing
------Do------	W_2	partial-span, double-slotted	----- -----	----- -----	0 50	Normal Landing
Original wing wing NACA outer panels	W_3	partial-span, single-slotted	0 20 40	----- ----- -----	----- ----- -----	Normal Take-off Landing
------Do------	W_3	partial-span, double-slotted	----- -----	----- -----	0 50	Normal Landing

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TABLE III

LIST OF FIGURES

Figure No.	Type of Presentation	Model Wing	Remarks
1	3-view of the model	W_1	Drawing
2	Details of midchord slot	W_2	Do
3(a) & 3(b)	Close up of midchord slot	W_2	Photograph
4	Rigging diagram and physical characteristics of the wing planforms	W_1, W_2, & W_3	Drawing
5(a)	Details of flap and aileron arrangement	W_1 & W_2	Do
5(b)	------------------Do------------------	W_3	Do
6(a) & 6(b)	Flap positions tested	W_1, W_2, & W_3	Do
7	Comparison of sealed ailerons	-----do-----	Do
8	Model set-up in test section	W_1	Photograph
9(a)	Stalling characteristics	W_1	Normal flight and landing conditions; $T_c = 0$; $R \approx 2,500,000$
9(b)	------------Do----------	W_1	Normal flight condition; propellers removed; $R \approx 5,500,000$
10	Leading-edge spoiler installation	W_1	Drawing
11(a)	Stalling characteristics	W_1	Normal flight condition; rated power; spoilers off and on; $R \approx 2,500,000$
11(b)	------------Do----------	W_1	Landing condition; 40-percent rated power; spoilers on and off; $R \approx 2,500,000$
12(a)	Aerodynamic characteristics of the model with leading-edge spoilers	W_1	C_D, α, C_m, vs C_L; normal flight condition; $R \approx 2,500,000$
12(b)	------------------Do---------------------	W_1	C_D, α, C_m, vs C_L landing condition; $R \approx 2,500,000$
13(a)	Stalling characteristics; full-span flaps	W_2	Normal flight, take-off, and landing conditions; propellers off; $R \approx 4,500,000$
13(b)	Stalling characteristics; partial-span, single-slotted flaps	W_2	Take-off and landing conditions; propellers off; $R \approx 4,500,000$
13(c)	Stalling characteristics; partial-span, double-slotted flaps	W_2	Normal flight, and landing conditions; propellers off; $R \approx 4,500,000$
14	Stalling characteristics	W_3	Do
15(a)	Aileron characteristics	W_1	C_l, C_L, vs α; normal flight condition; $R \approx 4,500,000$
15(b)	Aileron characteristics; full-span, single-slotted flaps	W_1	C_l, C_L, vs α; landing condition; $R \approx 4,500,000$
15(c)	Aileron characteristics; partial-span, single-slotted flaps	W_1	Do
16	Estimated helix angle	W_1	$\frac{pb}{2V}$ vs V_i; normal flight and landing conditions
17(a)	Aileron characteristics	W_2	C_l, C_L, vs α; normal flight condition; $R \approx 4,500,000$
17(b)	Aileron characteristics; full-span, single-slotted flaps	W_2	C_l, C_L, vs α; landing condition; $R \approx 4,500,000$
17(c)	Aileron characteristics; partial-span, single-slotted flaps	W_2	Do
17(d)	Aileron characteristics; partial-span, double-slotted flaps	W_2	Do
18	Estimated helix angle	W_2	$\frac{pb}{2V}$ vs V_i; normal flight and landing conditions
19(a)	Aileron characteristics	W_3	C_l, C_L, vs α; normal flight condition; $R \approx 4,500,000$
19(b)	Aileron characteristics; partial-span, double-slotted flaps	W_3	C_l, C_L, vs α; landing condition; $R \approx 4,500,000$
20	Estimated helix angle	W_3	$\frac{pb}{2V}$ vs V_i; normal flight and landing conditions

TABLE III (Concluded)

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Figure No.	Type of Presentation	Model Wing	Remarks
21(a) & 21(b)	Details of transition strips	W_3	Photograph
22(a)	Aerodynamic characteristics; full- and partial-span, single-slotted flaps	W_1	C_D, α, C_m, vs C_L; normal flight, take-off, and landing conditions; $R \approx 4,500,000$
22(b)	Aerodynamic characteristics; full-span, single-slotted flaps; fixed transition	W_1	C_D, α, C_m, vs C_L; normal flight and landing conditions; $R \approx 4,500,000$
23(a)	Aerodynamic characteristics; full-span and partial-span, single-slotted flaps	W_2	C_D, α, C_m, vs C_L; normal flight, take-off, and landing conditions; $R \approx 4,500,000$
23.(b)	Aerodynamic characteristics; partial-span, double-slotted flaps	W_2	C_D, α, C_m, vs C_L; normal flight and landing conditions; $\delta_e = 0°$ and $-10°$; $R \approx 4,500,000$
24(a)	Aerodynamic characteristics; partial-span, single-slotted flaps	W_3	C_D, α, C_m, vs C_L; normal flight, take-off, and landing conditions; $R \approx 4,500,000$
24(b)	Aerodynamic characteristics; partial-span, double-slotted flaps; natural and fixed transition	W_3	C_D, α, C_m, vs C_L; normal flight and landing conditions; $\delta_e = 0°$ and $-10°$; $R \approx 4,500,000$
25(a) & 25(b)	Details of flap-nacelle seals	W_3	Photograph
26	Aerodynamic characteristics; full- and modified flap-nacelle seals	W_3	C_D, α, C_m, vs C_L; landing condition; $R \approx 4,500,000$
27	Spanwise section-lift-coefficient distribution	W_1	C_l vs y; normal flight condition
28	--------------Do--------------	W_3	Do

TABLE IV - SUMMARY OF RESULTS AT R ≈ 4,500,000 — NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Model Configuration	Wing	Flap deflection (deg)			$C_{L_{max}}$	α at $C_{L_{max}}$ (deg)	C_L at $C_m=0$	C_D		$\frac{pb}{2V}$ at $1.1V_s$		Figure No.
		δ_{f_1}	δ_{f_o}	δ_{f_s}				$C_L=0.4$	$C_L=0.8$	$\delta_a=+20 -25$	$\delta_a=\pm20$	
	W_1	0	0	---	1.33	19.0	1.01	0.026	0.040	----	0.060	15(a),16, & 22(a)
	W_1	20	50	---	1.75	13.3	1.08	----	.098	----	----	22(a)
	W_1	40	50	---	1.99	11.5	1.37	----	----	----	.031	15(b),16, & 22(a)
	W_1	40	---	---	1.95	18.4	1.54	.102	.108	----	.051	15(c),16, & 22(a)
	W_2	0	0	---	1.38	18.1	1.05	.030	.043	----	.062	17(a),18, & 23(a)
	W_2	20	50	---	1.86	16.0	1.10	----	.099	----	----	23(a)
	W_2	40	50	---	2.12	14.6	1.38	----	----	----	.039	17(b),18, & 23(a)
	W_2	40	---	---	2.04	15.6	1.50	.105	.113	----	.053	17(c),18, & 23(a)
	W_2	---	---	50	2.24	15.7	1.85	----	----	0.070	.063	17(d),18, & 23(b)
	W_3	---	---	0	1.35 / *1.40	21.1	1.05 / *1.11	---- / *.028	---- / *.042	.076	.069	19(a),20, & 24(a)
	W_3	20	---	---	1.63 / *1.69	16.3	1.44 / *1.51	---- / *.064	---- / *.073	----	----	24(a)
	W_3	40	---	---	1.88 / *1.95	16.6	1.70 / *1.75	---- / ---	---- / *.115	----	----	24(a)
	W_3	---	---	50	2.10 / *2.18	16.8	1.88 / *1.91	---- / ----	---- / ----	.076 / ----	.063 / ----	19(b),20, & 24(b)

*Coefficients based on area of W_1

NOTE:

All dimensions in inches

0 10 20
Scale (inches)
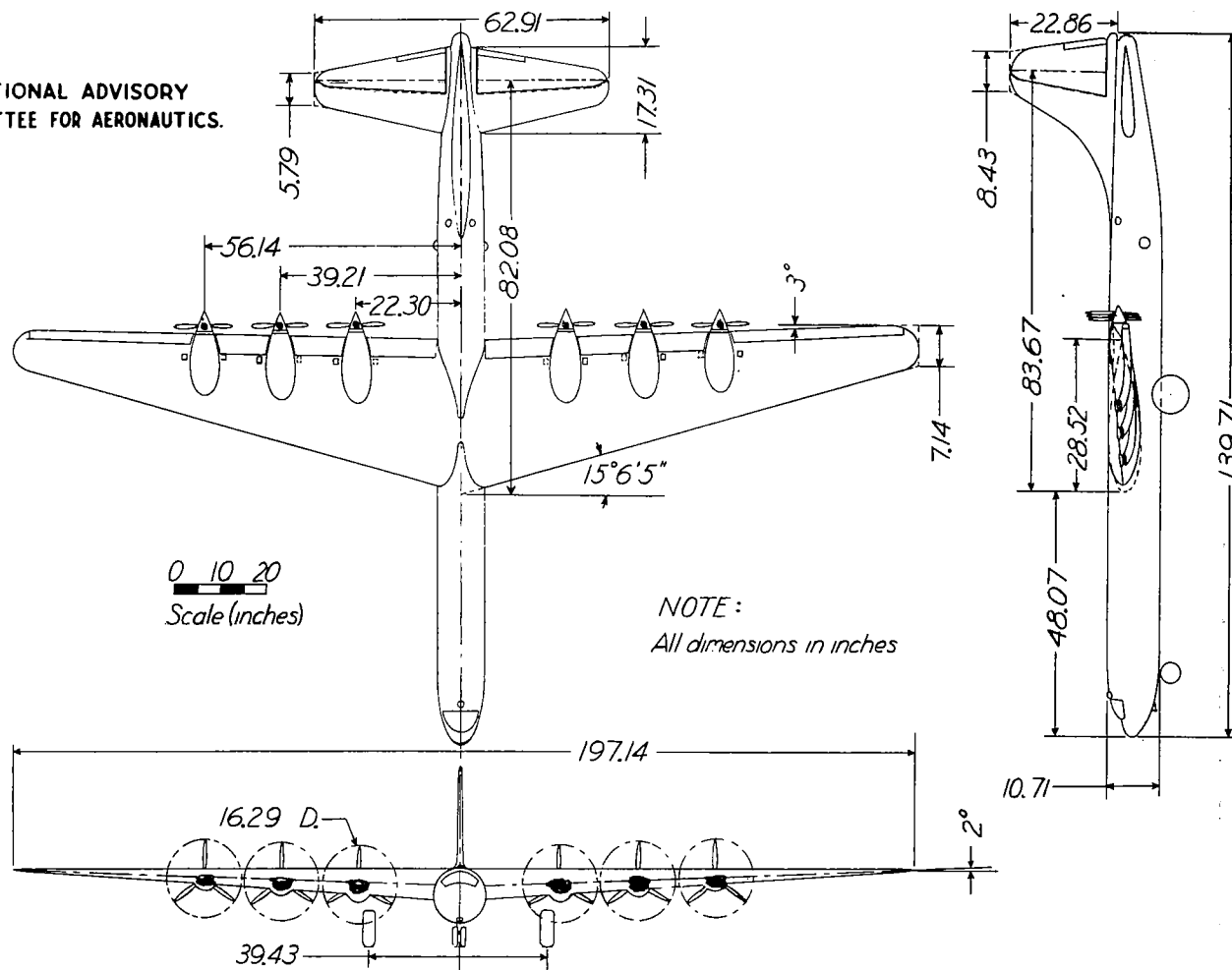
Figure 1.—Three-view drawing of a 1/14-scale model of the XB-36 airplane. Wing W₁.

1.0

.60

.075

Tangent point

.047

Wing chord line

.57

.162

.02

.17

.02

.079

.44

.06

.524

.61

.65

.664

Typical section
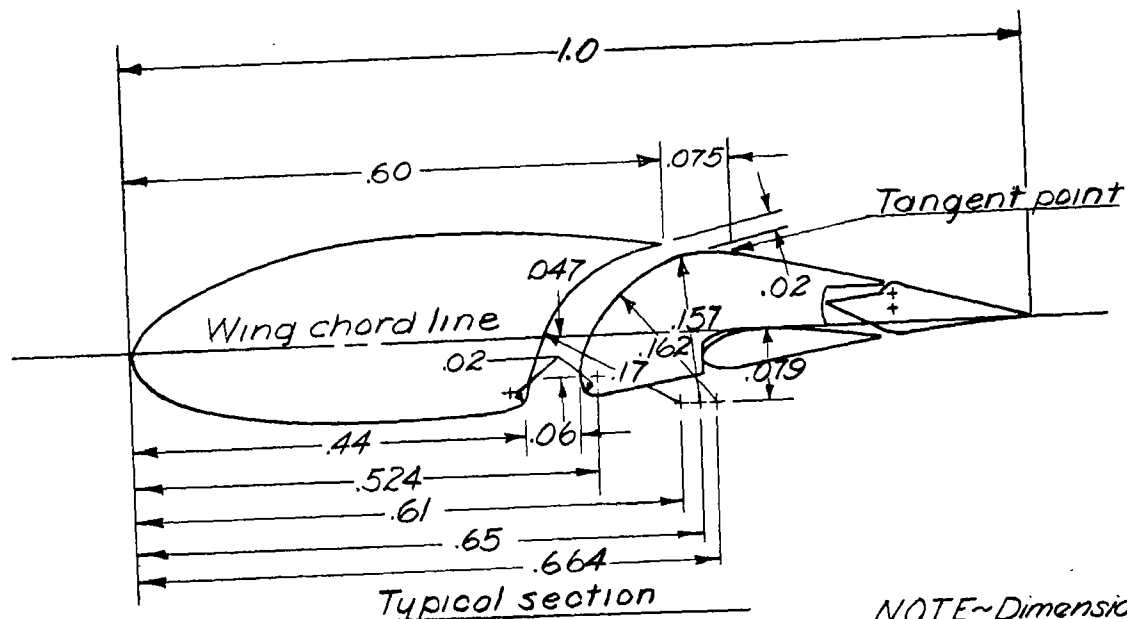
NOTE~Dimensions in fraction
of wing section chord.

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Sta.63.14

.44

.50

Sta.90.29

.60

.675

1"(Typ)

Plan view
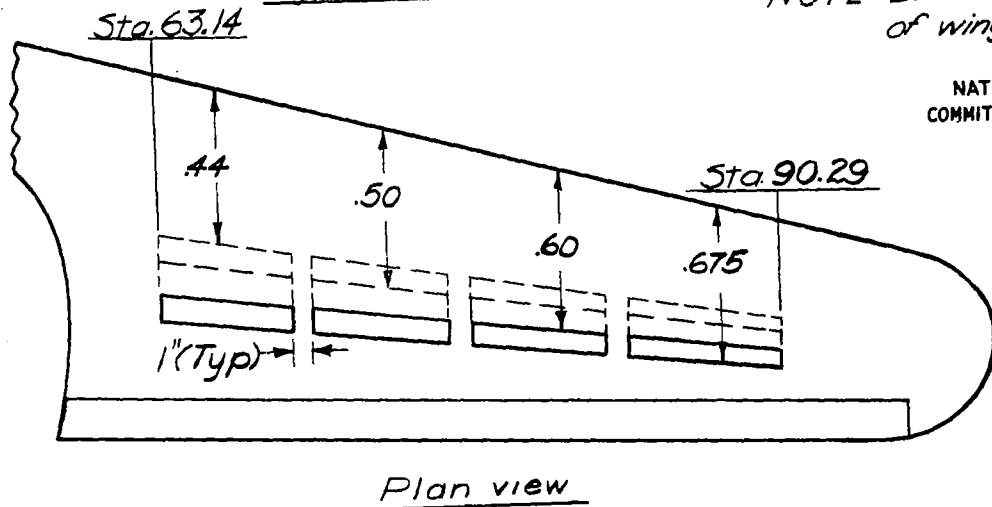
Figure 2 .— Midchord slot installation; 1/14-scale model of
the XB-36 airplane.
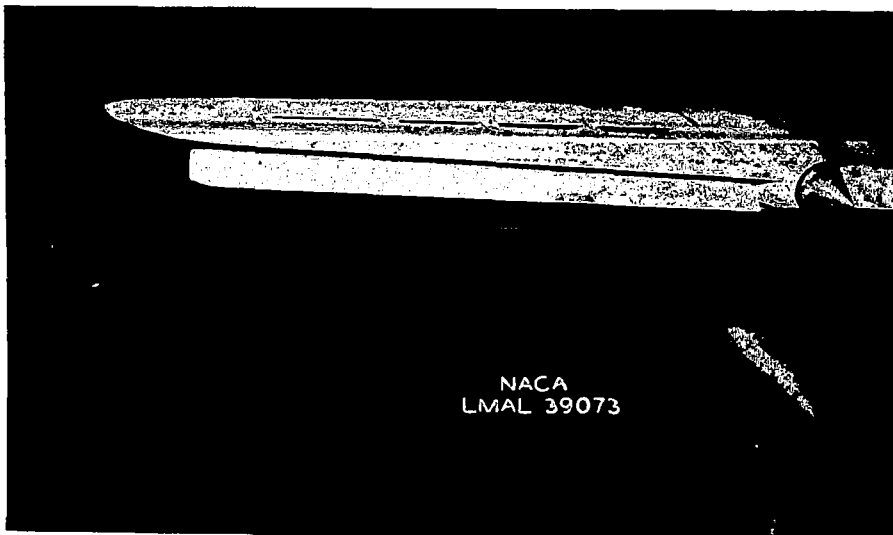
(a) Wing upper surface.
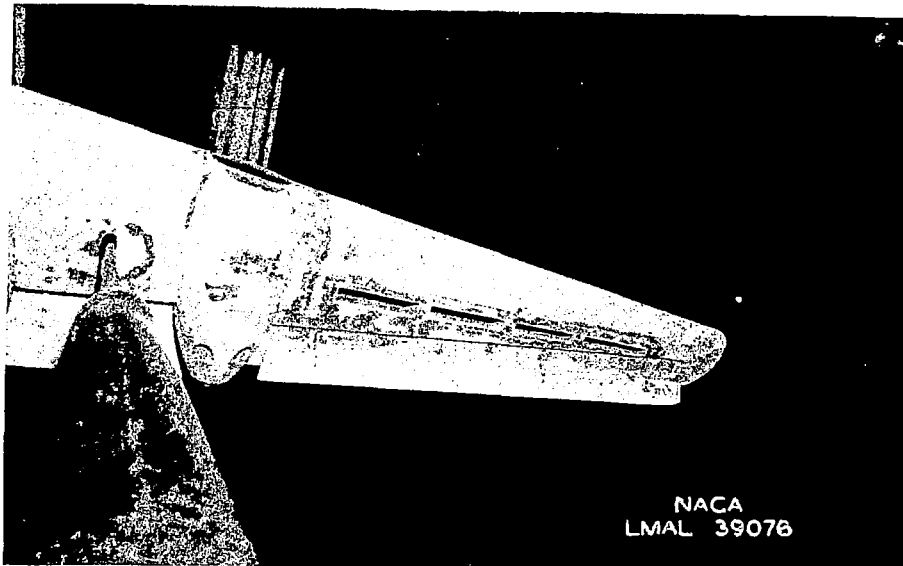
(b) Wing lower surface.

Figure 3.- Midchord slot; $\frac{1}{14}$-scale model of the XB-36 airplane.

~ Model Wing Data ~

	$W_1 \, \xi \, W_2$	W_3
Airfoil section-		
root	NACA 63(420)-422	NACA 63(420)-422
tip	NACA 63(420)517	NACA 65(348) 517
Area (sq. ft)	24.347	25.281
Span	197.142	197.142
Root chord	28.531	28.531
Tip chord	7.142	10.712
Mean aerodynamic chord (MAC)	20.050	20.241
Sweepback of L.E. (outb'd of Sta 60.998)	15°6' 5"	11°21'
Sweepback of T.E. (outb'd of Sta 60.998)	3°	4°27'36"
Taper ratio	4.000	2.666
Dihedral (from wing root chord plane)	2°	2°
Angle of incidence at wing root chord	3°	3°
Root thickness (% root chord)	22	22
Tip thickness (% tip chord)	17	17
Aspect ratio	11.085	10.676
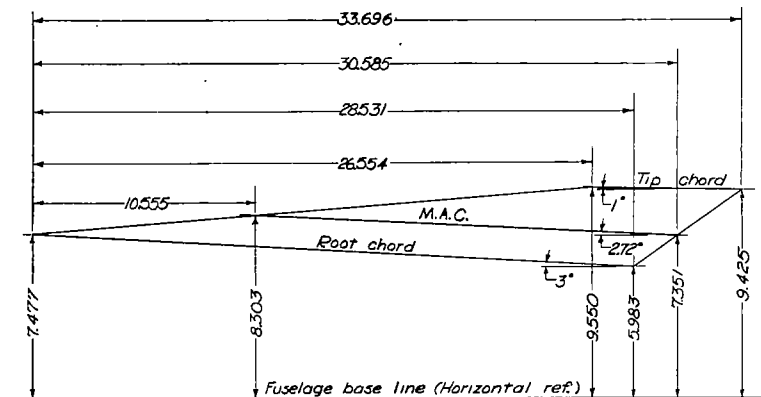
NOTE~ All dimensions are given in inches

Tip chord

M.A.C.

Root chord

Fuselage base line (Horizontal ref.)

Rigging diagram~ $W_1 \, \xi \, W_2$

0 1 2 3 4 5
Scale (in)

33.696
30.585
28.531
26.554
10.555

7.477
8.303
9.550
5.983
7.351
9.425

¢ Wing

Planform

0 1 2 3 4 5
Scale (in)

34.661
32.714
31.728
28.531
23.949
18.949
16.431

Tip chord
Sta 73.632
Sta 60.998

Root chord

Fuselage base line (Horizontal ref.)

Rigging diagram~ W_3

0 1 2 3 4 5
Scale (in)

7.477
8.759
8.554
9.238
5.983
8.113
8.554
9.425
28.531

15°6'5"
L.E.
11°21'
$W_1 \, \xi \, W_2$ W_3
3°
T.E.
4°27'36"
60.998
98.571
2.606
7.142
0.964
0.960
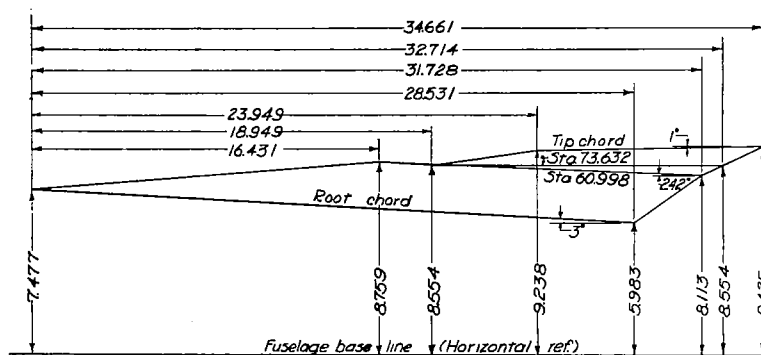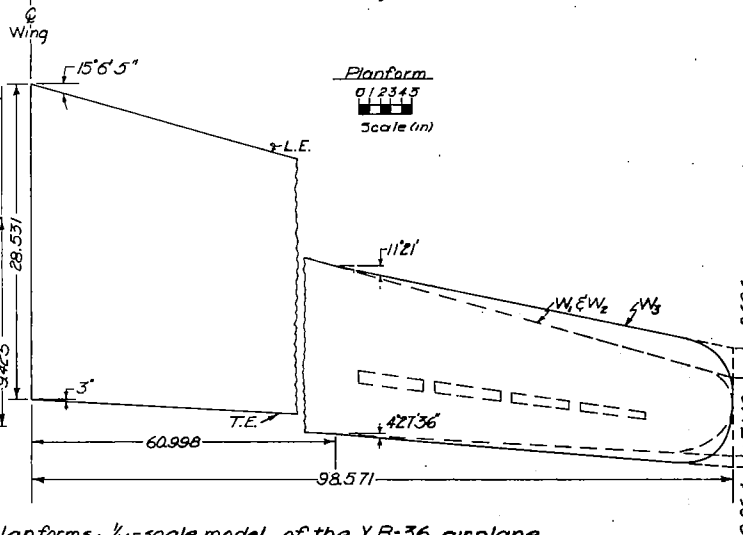
Figure 4.- Comparison of physical characteristics of two wing planforms; 1/14-scale model of the XB-36 airplane.

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0   5   10   15

Scale (in)

NOTE ~ All dimensions are given in inches

Leading edge

A

B

3.64

3.64

3.64

35.64

2.43

1.35

37.20

13.57

10.78

10.99

B

A

98.57

Plan view

1.93

1.71

0.11

0.39

1.71 R.

Wing chord line

0.40 R.

0.60

1.99

Section A-A

0.80

0.04

Aileron

0.63 R

Wing chord line

Flap

2.50

1.81

4.31

Section B-B

0   0.5   1.0   1.5   2.0

Scale (in.)

0   0.5   1.0   1.5   2.0

Scale (in.)

Hinge point

5.36
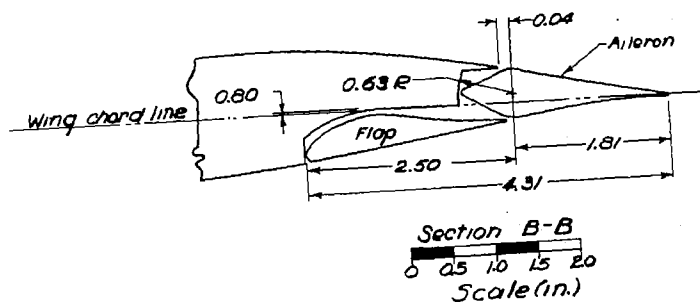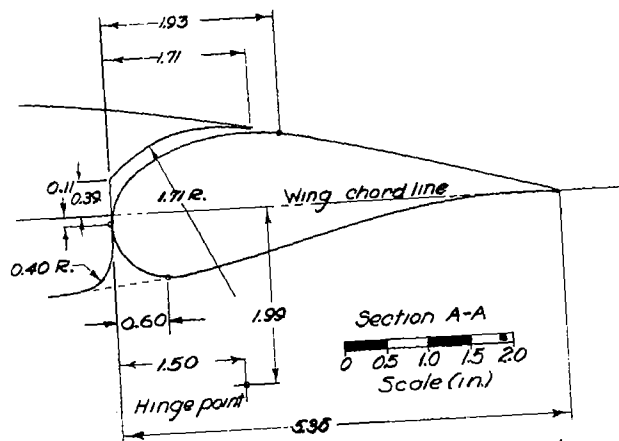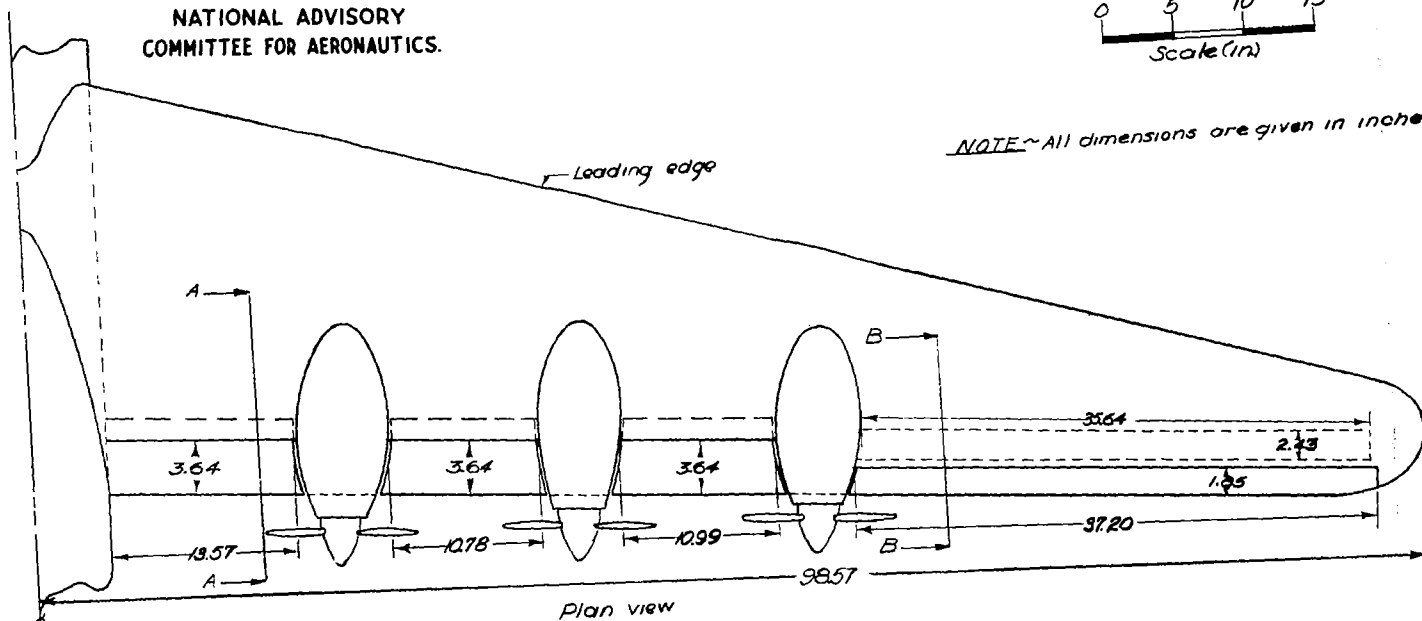
Figure 5(a).- Plan and section views of flap and aileron installation; 1/14-scale model of the XB-36 airplane. Wing W₁.

Scale (in.)
0   5   10   15

NOTE~ All dimensions are given in inches

Leading edge

A

B

3.64   3.64   3.64   2.23

13.57   10.78   10.99   3.950

98.57

Plan view

A

B

1.99
1.71

0.11
0.39   1.71R   Wing chord line

0.40R

0.06   1.99
1.50   Section A-A

Scale (in.)
0   0.5   1.0   1.5   2.0

Hinge point

5.36

Wing chord line

℄ Hinge

2.23

.07R

R taken at hinge ℄
to be tangent to contour.

20°   35°
50°   30°

Section B-B

Scale (in.)
0   0.5   1.0   1.5   2.0

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Figure 5(b).- Plan and section views of flap and aileron installation, 1/14-scale model of the XB-36 airplane. Wing W_3.

g-Wing chord line

1.99

Hinge point

3.86

20°

40°

Station 53.64   (typ.)

Chord = 16.91

.094

Extended lip

g-Wing chord line

NOTE~ All dimensions are given in inches.

50°

3.92

Station 53.64   (typ.)

|0 |1 |2 |3
Scale (inches)

(a) Single- and double-slotted inboard flaps.

Figure 6.— Flap positions tested; 1/14-scale model of the XB-36 airplane.

line

$\delta_{f_0} = 0°$

$50°$
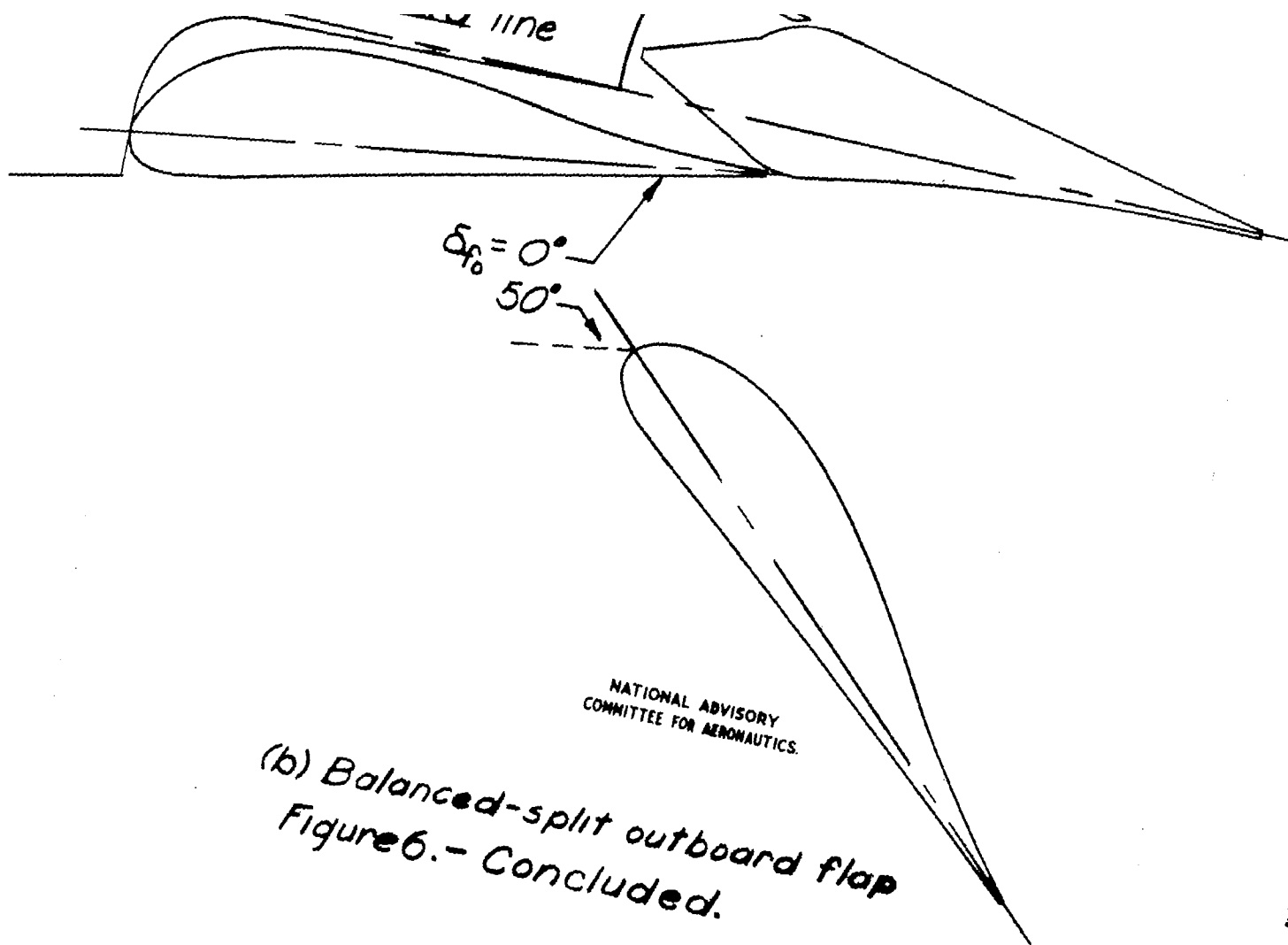
(b) Balanced-split outboard flap

Figure 6.- Concluded.
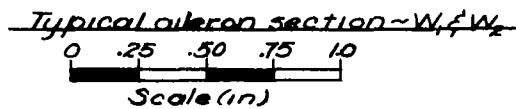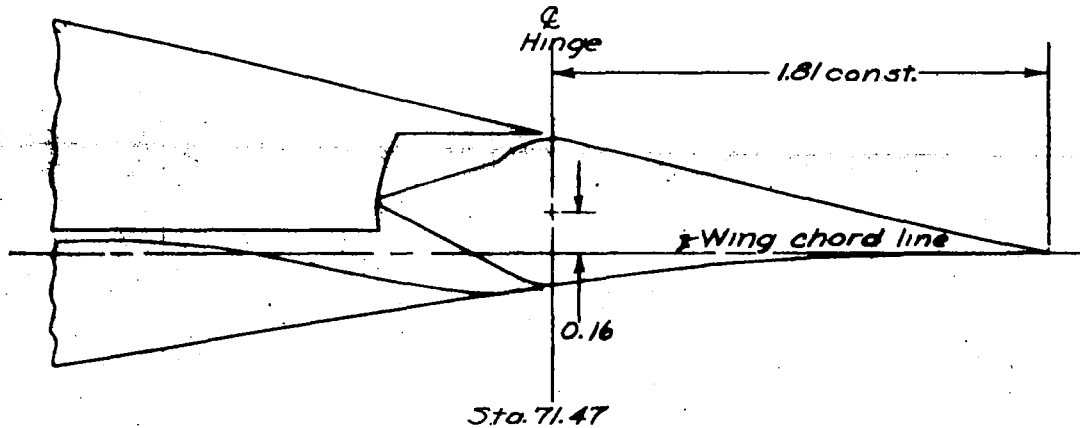
ℓ Hinge

1.81 const.

Wing chord line

0.16

Sta. 71.47

Typical aileron section ~ W₁ & W₂

0   .25   .50   .75   1.0

Scale (in)

NOTE ~ All dimensions are given in inches

ℓ Hinge

2.23 const.

0.07 R.

ℓ Wing chord line

Sta. 73.63

Typical aileron section ~ W₃

0   .25   .50   .75   1.0

Scale (in)
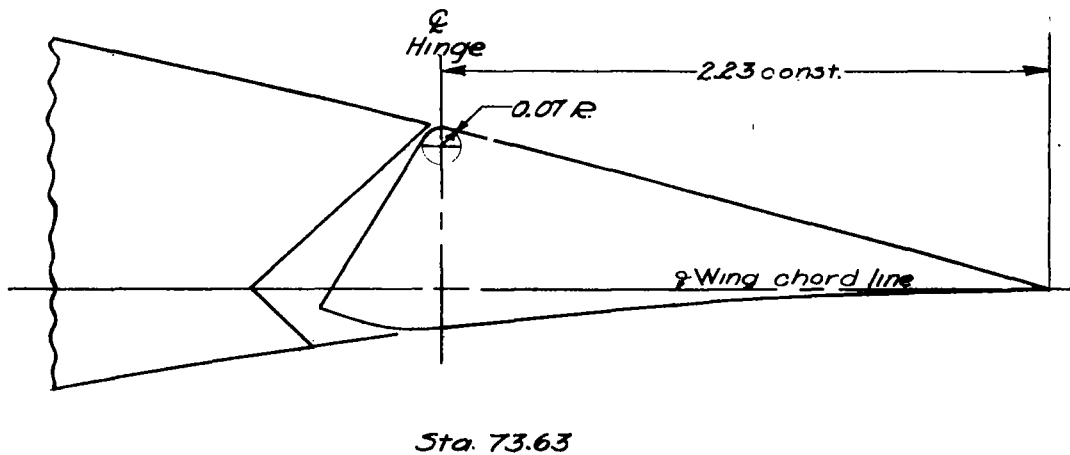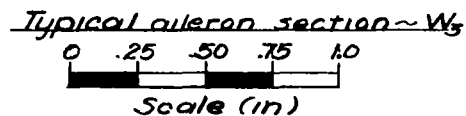
Figure 7. - Comparison of sealed ailerons used
in tests of a 1/14-scale model of the XB-36 airplane.
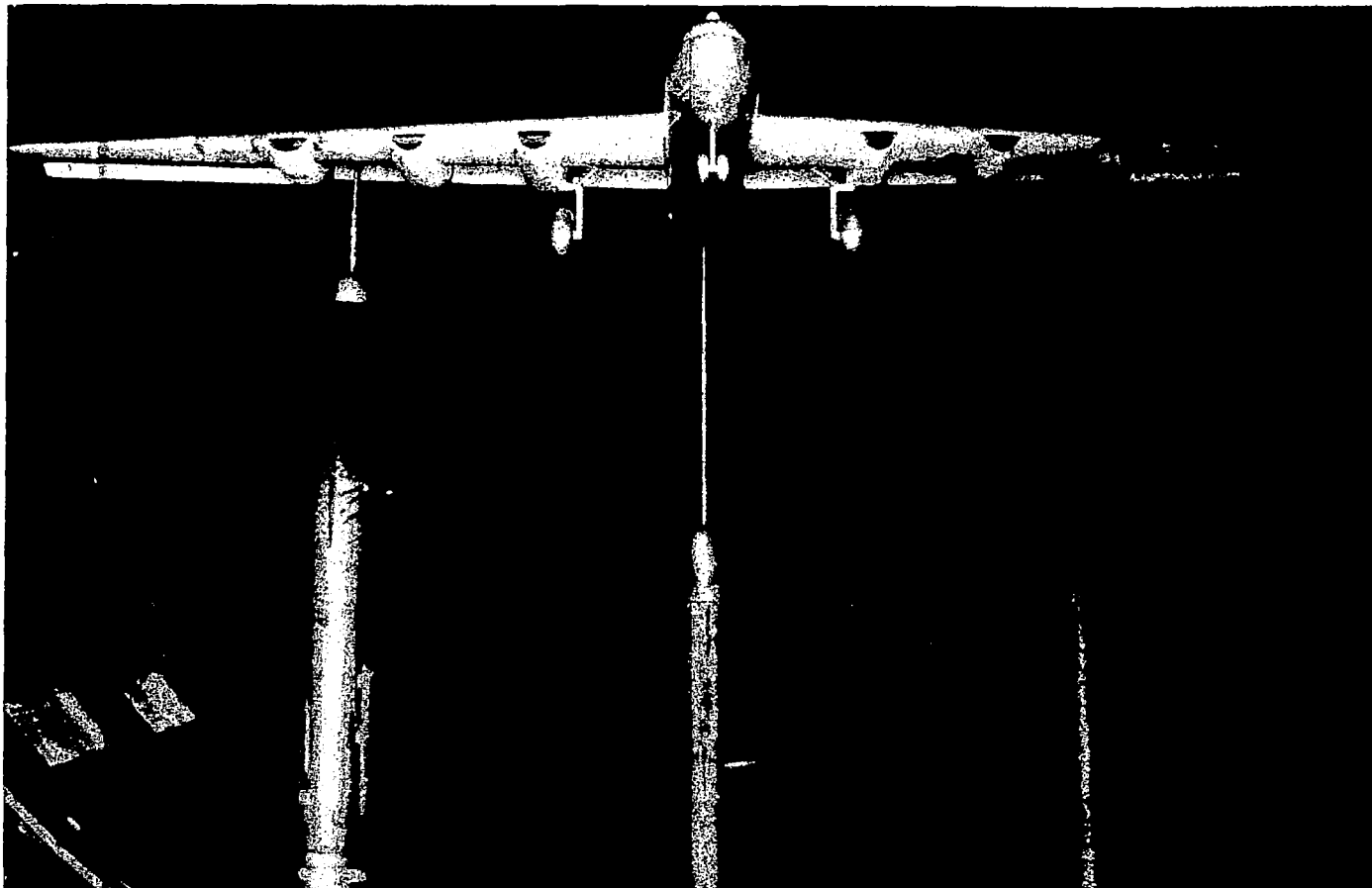
Figure 8.- A $\frac{1}{14}$-scale model of the XB-36 airplane mounted on the normal supports in the test section of the Langley 19-foot pressure tunnel.
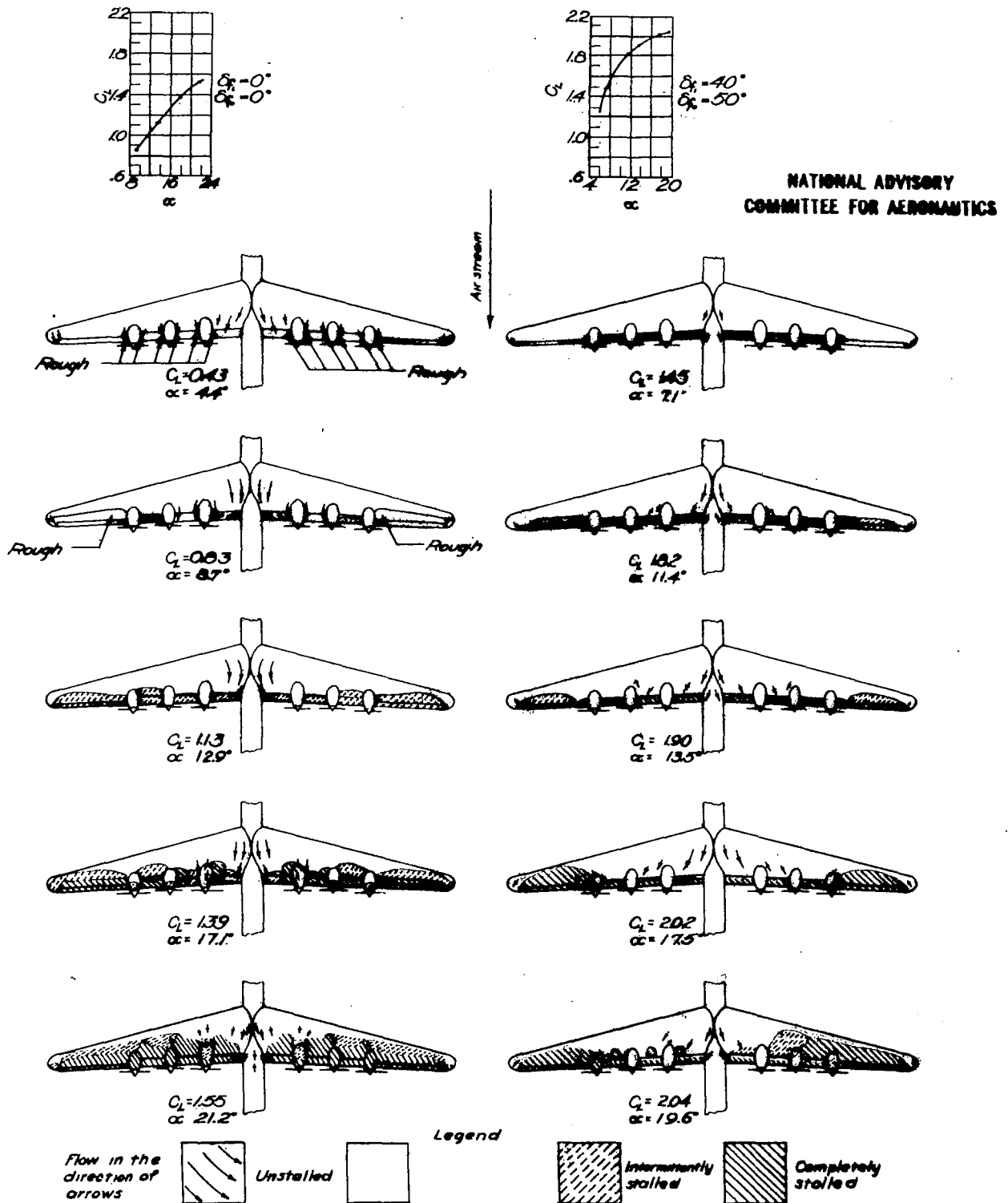
(a) Zero thrust; $R \approx 2,500,000$; $M \approx 0.09$.

Figure 9.—Stall studies of a 1/14-scale model of the XB-36 airplane. Wing W_1; original tail.

Rough — $C_L = 0.67$ $\alpha = 6.6°$ — Rough

Rough — $C_L = 0.86$ $\alpha = 8.7°$ — Rough

Rough — $C_L = 1.01$ $\alpha = 10.6°$ — Rough

$C_L = 1.14$ $\alpha = 12.9°$

Rough — Rough — $C_L = 1.22$ $\alpha = 15.0°$

Rough — $C_L = 1.51$ $\alpha = 7.2°$ — Rough

Rough — $C_L = 1.70$ $\alpha = 9.3°$ — Rough

Rough — $C_L = 1.87$ $\alpha = 11.4°$

$C_L = 1.90$ $\alpha = 13.5°$

$C_L = 1.87$ $\alpha = 15.4°$

Legend

Flow in the direction of arrows — Unstalled — Intermittently stalled — Completely stalled
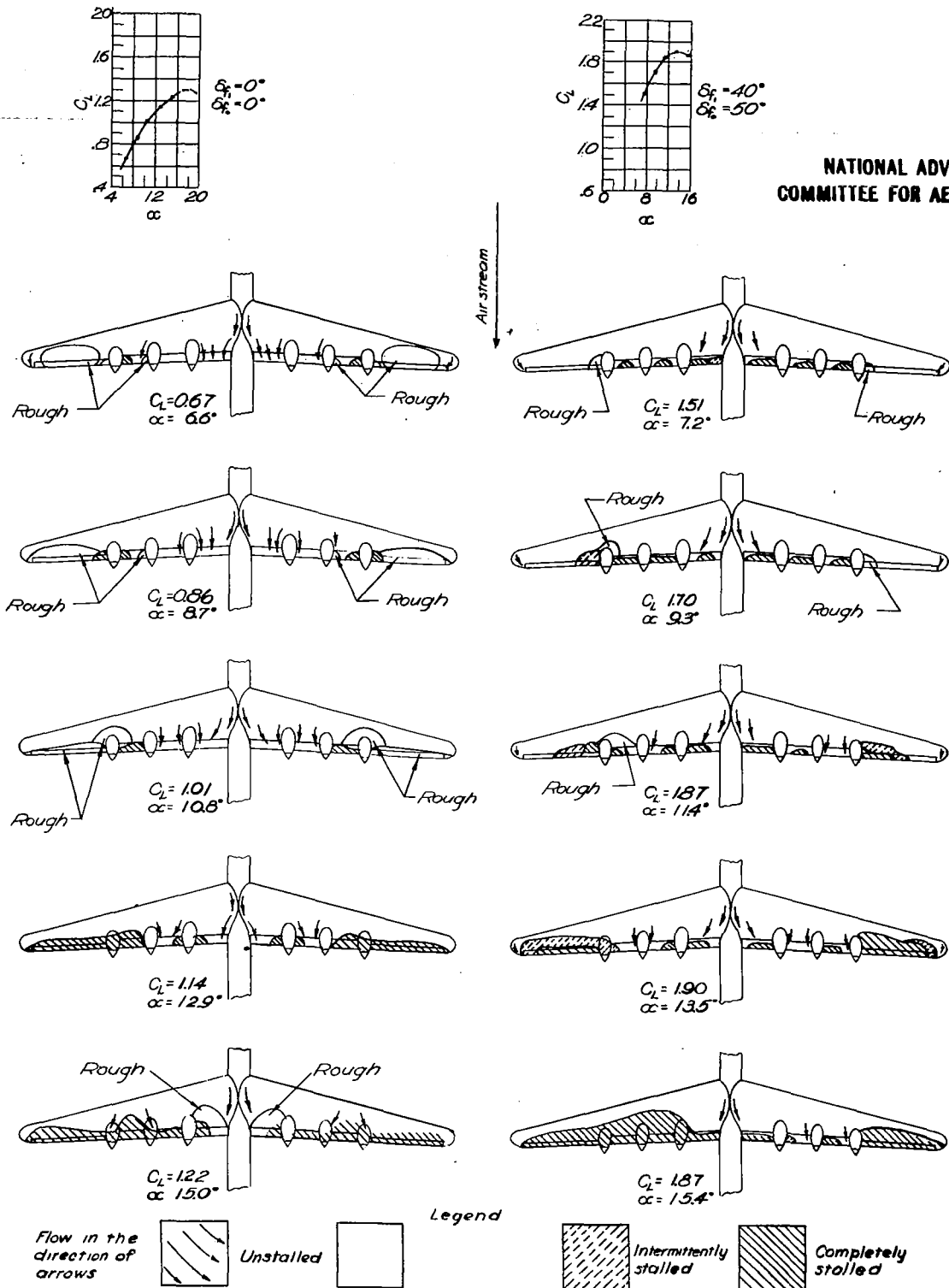
(b) Propellers removed; $R \approx 5,500,000$; $M \approx 0.20$.

Figure 9 .— Concluded.

Plan view

Section A-A

wing chord line
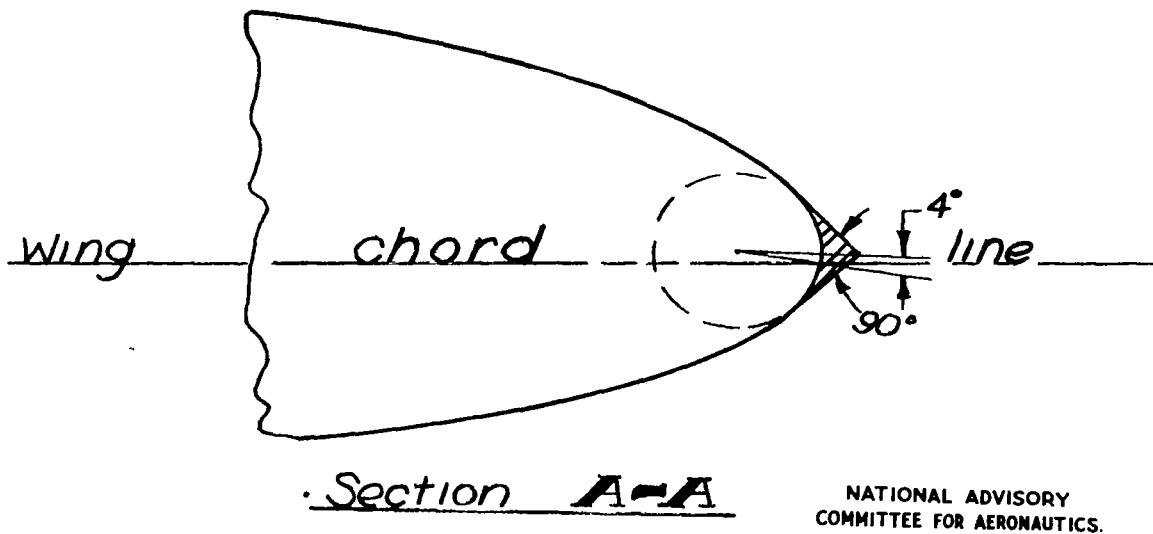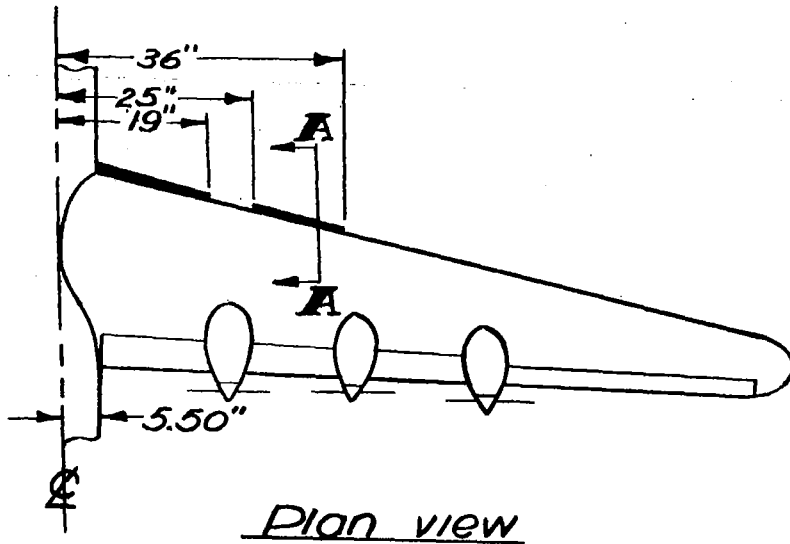
Figure 10.- Plan and section views of a leading-
edge spoiler arrangement; 1/14-scale
model of the XB-36 airplane.

Spoiler off

Spoiler on

Air stream

$C_L=0.87$
$\alpha=8.7°$
$T_C=0.076$

$C_L=0.85$
$\alpha=8.7°$
$T_C=0.073$

$C_L=1.06$
$\alpha=10.9°$
$T_C=0.101$

$C_L=1.04$
$\alpha=10.8°$
$T_C=0.098$

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$C_L=1.42$
$\alpha=15.1°$
$T_C=0.151$

Rough

$C_L=1.22$
$\alpha=13.0°$
$T_C=0.123$

$C_L=1.59$
$\alpha=17.2°$
$T_C=0.175$

$C_L=1.38$
$\alpha=15.1°$
$T_C=0.145$

$C_L=1.84$
$\alpha=20.4°$
$T_C=0.213$

$C_L=1.52$
$\alpha=17.2°$
$T_C=0.165$

Legend

Flow in the
direction of
arrows

Unstalled

Intermittently
stalled

Completely
stalled
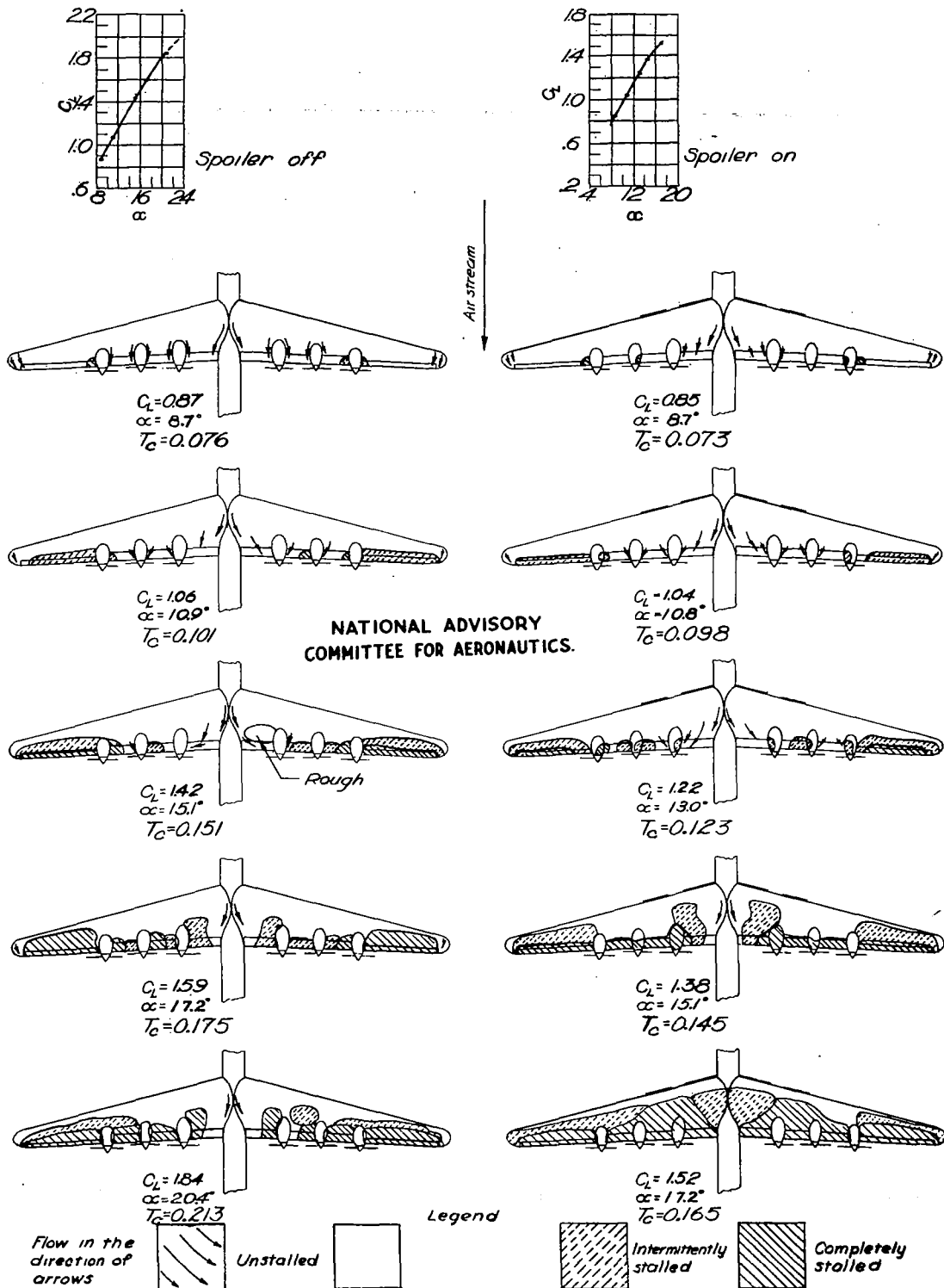
(a) $\delta_{f_L}=0°$; $\delta_{f_D}=0°$; Rated power @ S.L.; $R\approx2,500,000$; $M=0.09$.

Figure 11.- Effect of a leading-edge spoiler on the stall progression of a 1/14-
scale model of the XB-36 airplane. Wing W_1; original tail.
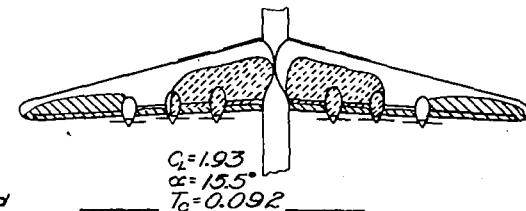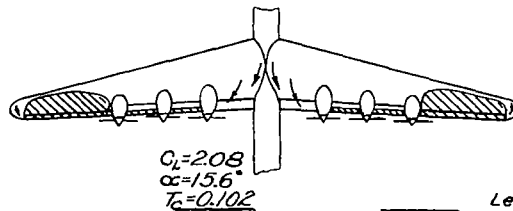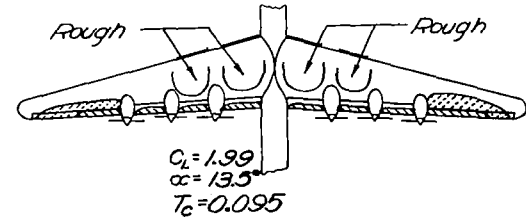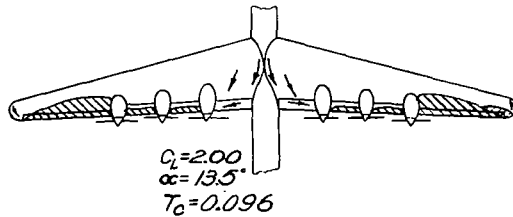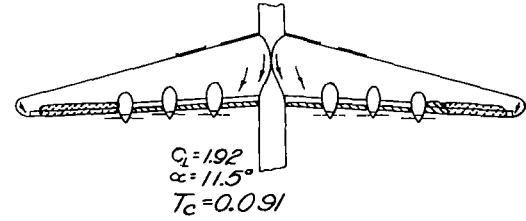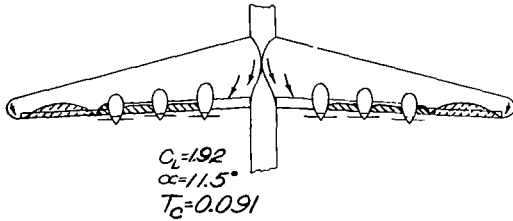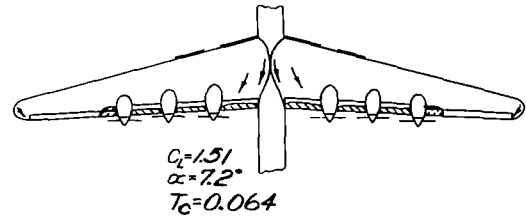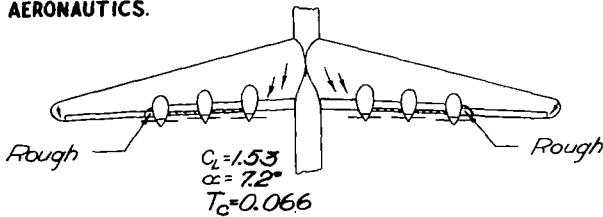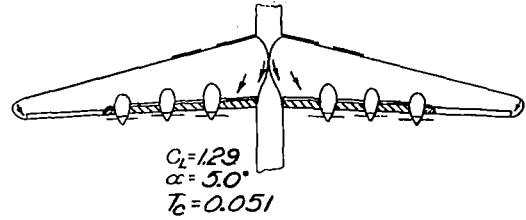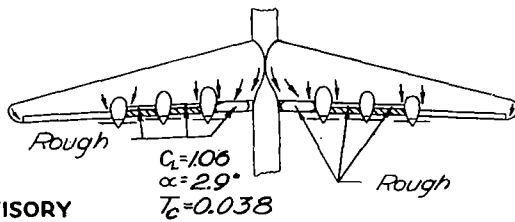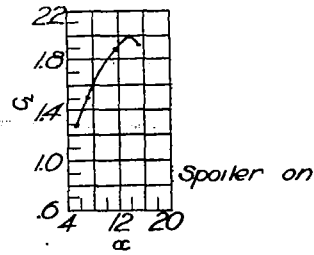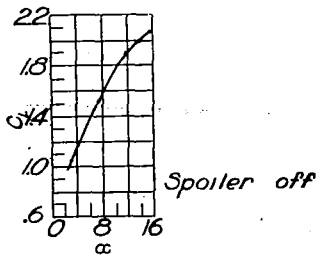
Air stream

Spoiler off

Spoiler on

Rough
$C_L = 1.06$
$\alpha = 2.9°$
$T_c = 0.038$
Rough

$C_L = 1.29$
$\alpha = 5.0°$
$T_c = 0.051$

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Rough
$C_L = 1.53$
$\alpha = 7.2°$
$T_c = 0.066$
Rough

$C_L = 1.51$
$\alpha = 7.2°$
$T_c = 0.064$

$C_L = 1.92$
$\alpha = 11.5°$
$T_c = 0.091$

$C_L = 1.92$
$\alpha = 11.5°$
$T_c = 0.091$

$C_L = 2.00$
$\alpha = 13.5°$
$T_c = 0.096$

Rough   Rough
$C_L = 1.99$
$\alpha = 13.5°$
$T_c = 0.095$

$C_L = 2.08$
$\alpha = 15.6°$
$T_c = 0.102$

$C_L = 1.93$
$\alpha = 15.5°$
$T_c = 0.092$

Legend

Flow in the
direction of
arrows   Unstalled

Intermittently   Completely
stalled   stalled

(b) $\delta_{f_i} = 40°$; $\delta_c = 50°$; 40% Rated power @ S.L.; $R \approx 2,500,000$; $M = 0.09$.
Figure 11 .- Concluded.

Figure 12.—Effect of a leading-edge spoiler arrangement on the aerodynamic characteristics of a 1/14 scale model of the XB-36 airplane wing with original tail.
$R \approx 2,300,000; M \approx 0.09$

(a) $\delta_{f_n} = 0°; \delta_{f_e} = 0°$

(b) $\delta_e = 40°; \delta_a = 50°$

Figure 12.- Concluded.

Airstream

$\delta_{f_i} = 0°$
$\delta_{f_o} = 0°$

$\delta_{f_i} = 20°$
$\delta_{f_o} = 50°$

$\delta_{f_i} = 40°$
$\delta_{f_o} = 50°$

Legend

Flow in the direction of arrows

Unstalled

Intermittently stalled

Completely stalled

$C_L = 0.76$
$\alpha = 7.6°$

$C_L = 1.57$
$\alpha = 10.2°$

Rough $C_L = 1.86$ Rough
$\alpha = 10.4°$

Rough $C_L = 0.92$ Rough
$\alpha = 9.8°$

$C_L = 1.72$
$\alpha = 12.3°$

Rough $C_L = 1.99$ Rough
$\alpha = 12.5°$

Rough $C_L = 1.08$ Rough
$\alpha = 11.9°$

Rough $C_L = 1.82$ Rough
$\alpha = 14.4°$

Rough $C_L = 2.09$ Rough
$\alpha = 14.6°$

Rough $C_L = 1.18$ Rough
$\alpha = 13.9°$

Rough $C_L = 1.84$ Rough
$\alpha = 15.4°$

Rough $C_L = 2.10$
$\alpha = 15.6°$

Rough $C_L = 1.31$
$\alpha = 16.0°$

$C_L = 1.86$
$\alpha = 18.4°$
(a) Full-span flaps.

$C_L = 2.10$
$\alpha = 17.6°$

Figure 13. - Stall studies of a 1/14-scale model of the XB-36 airplane; Wing W_2, $R \approx 4,500,000$, $M \approx 0.17$
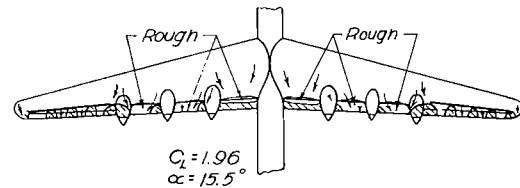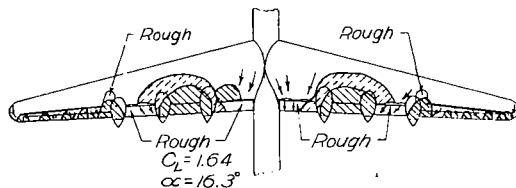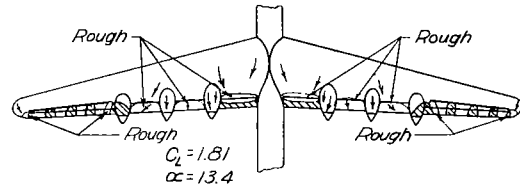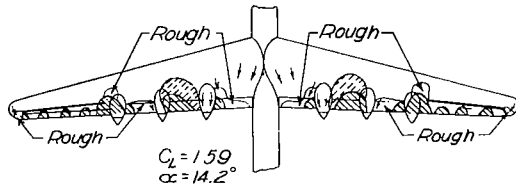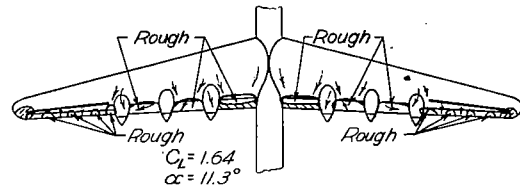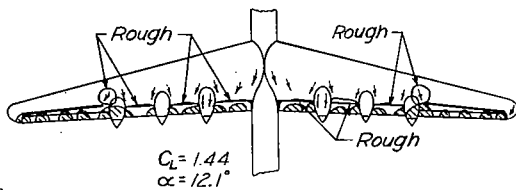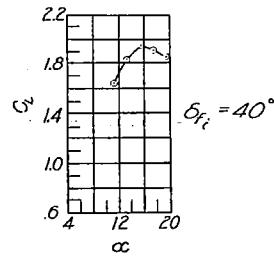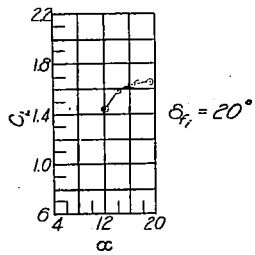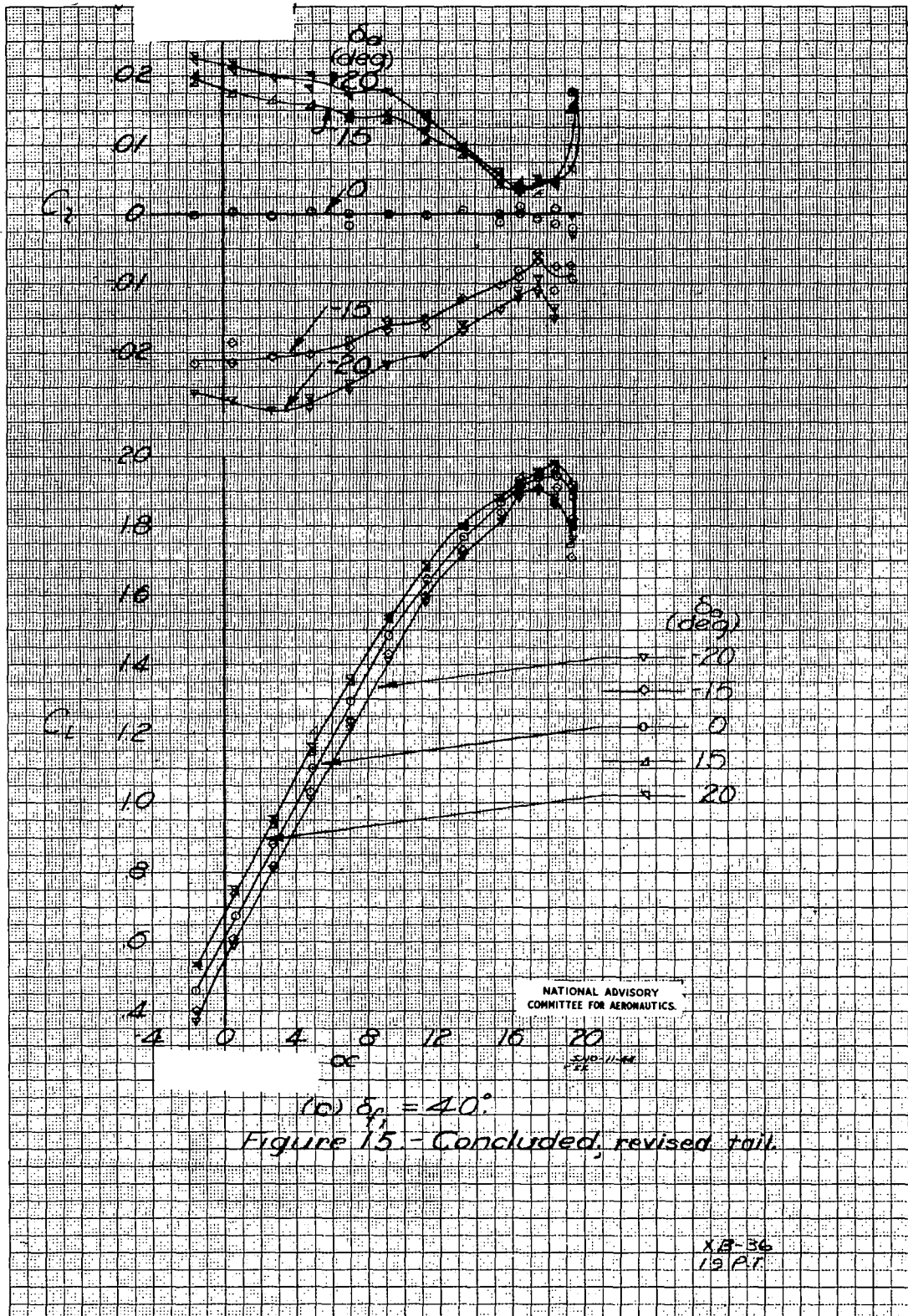
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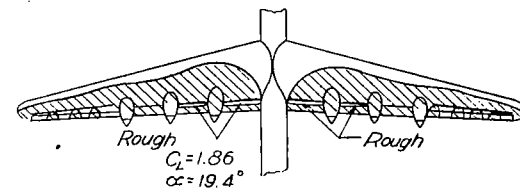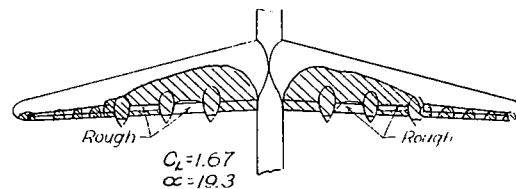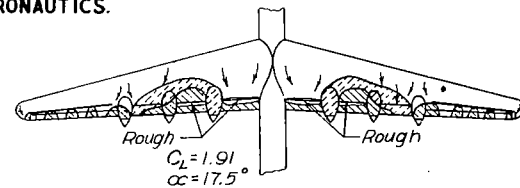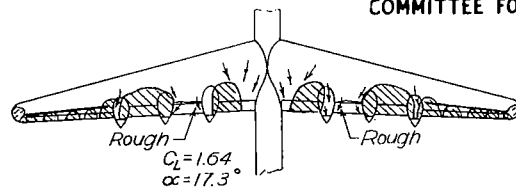
(b) Partial-span, single-slotted flaps.
Figure 13.— Continued.
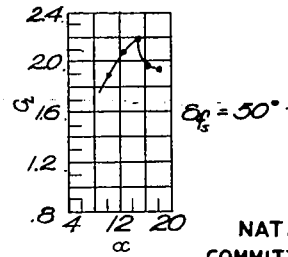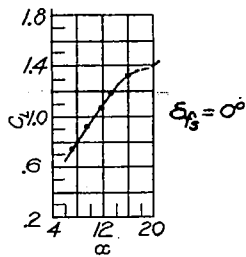
$\delta_{f_S} = 0°$

$\delta_{f_S} = 50°$

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Air stream

$C_L = 0.76$
$\alpha = 7.6°$

Rough $C_L = 1.88$
$\alpha = 10.4°$

Rough $C_L = 0.92$
$\alpha = 9.8°$ Rough

Rough $C_L = 2.06$
$\alpha = 12.6°$

Rough $C_L = 1.08$
$\alpha = 11.9°$ Rough

Rough $C_L = 2.19$
$\alpha = 14.7°$

Rough $C_L = 1.18$
$\alpha = 13.9°$ Rough

Rough $C_L = 1.95$
$\alpha = 16.5°$

Rough $C_L = 1.31$
$\alpha = 16.0°$ Rough

Rough $C_L = 1.91$
$\alpha = 18.5°$

Legend

Flow in the
direction of
arrows — Unstalled — Intermittently stalled — Completely stalled

(c) Partial-span, double-slotted flaps.
Figure 13.—Concluded.
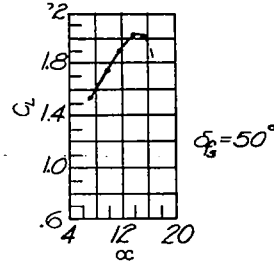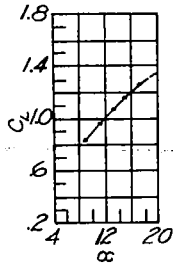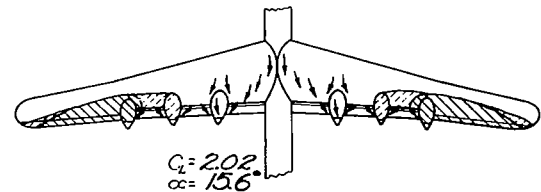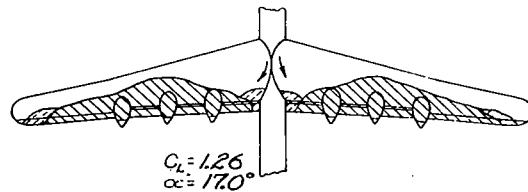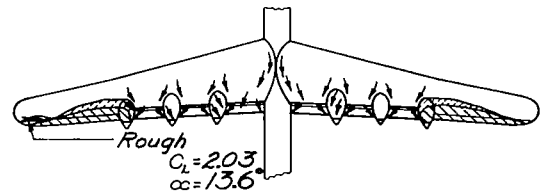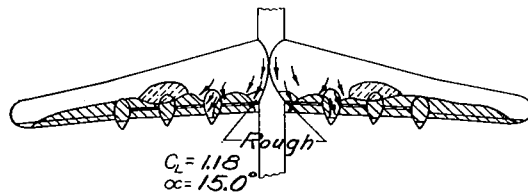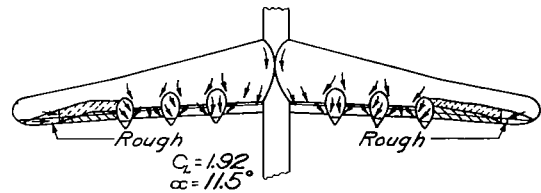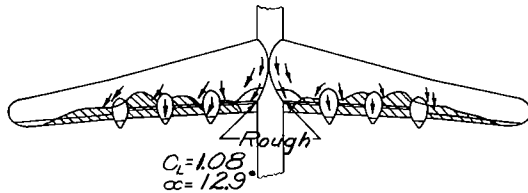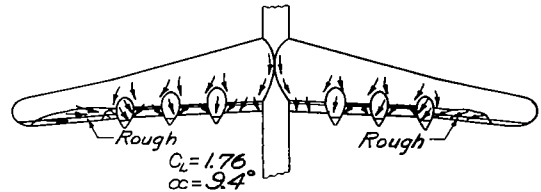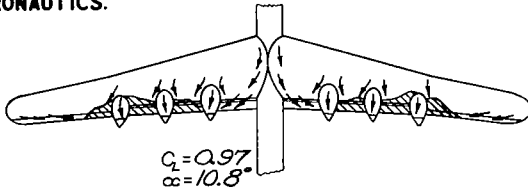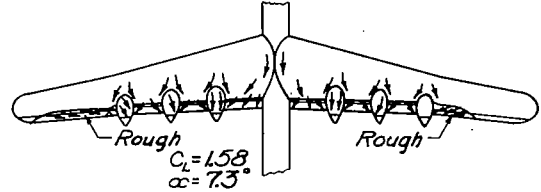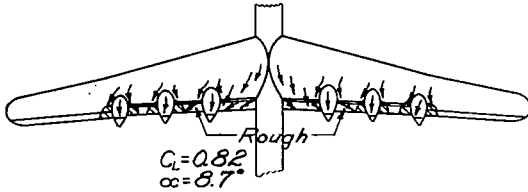
Figure 14 - Stall studies of a 1/14-scale model of the XB-36 airplane. Wing W_3, $R \approx 4,500,000$; $M \approx 0.17$.
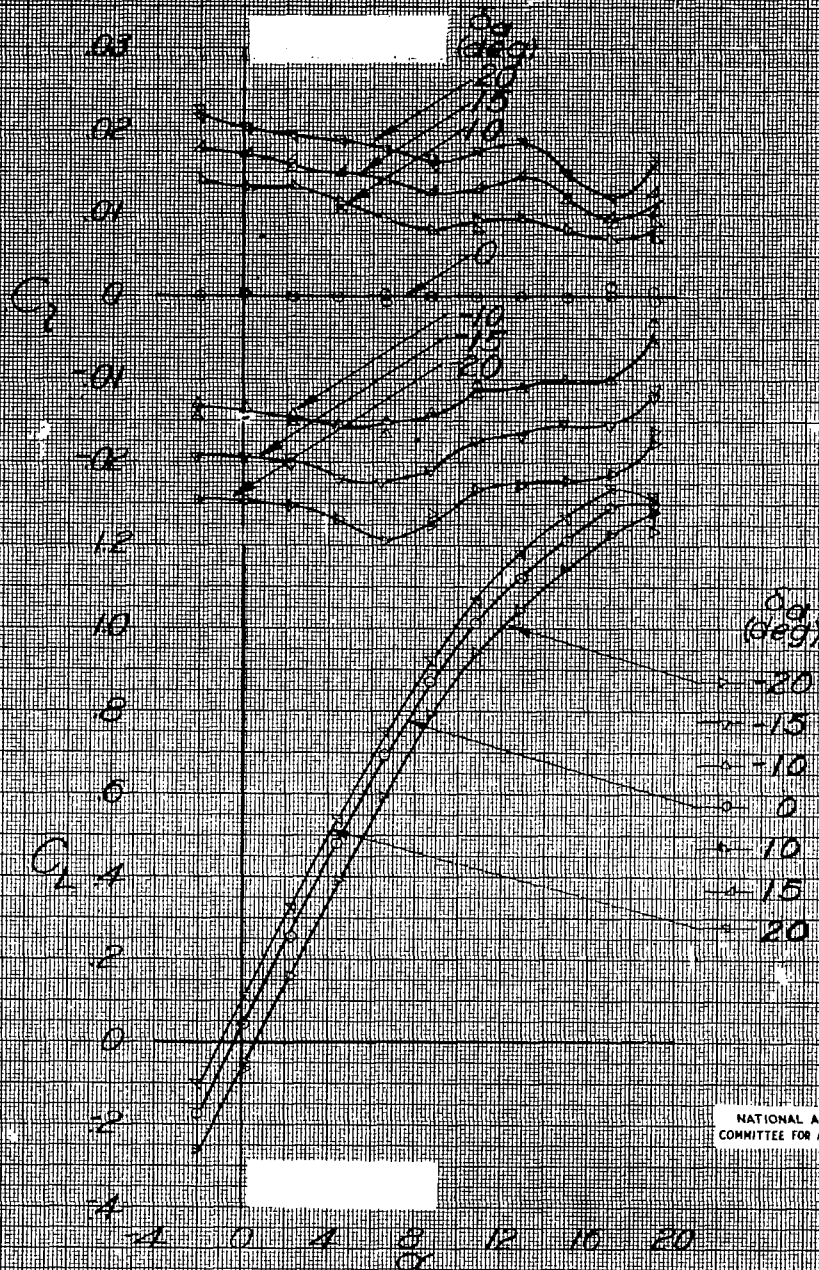
Figure 13.- Aileron characteristics of a 1/14-scale model of the XB-36 airplane. Wing W; original tail; R≈4,500,000, M≈0.17

(b) $\delta_{f_i} = 40°;\ \delta_{f_b} = 50°$

Figure 15.- Continued, original tail

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(a) $\delta_{f_1} = 40°$

Figure 15.- Concluded, revised tail.

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Figure 16.— Estimated helix angle for XB-36 airplane with original wing W_1.

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(a) $\delta_{f_i} = 0°$; $\delta_{f_o} = 0°$.
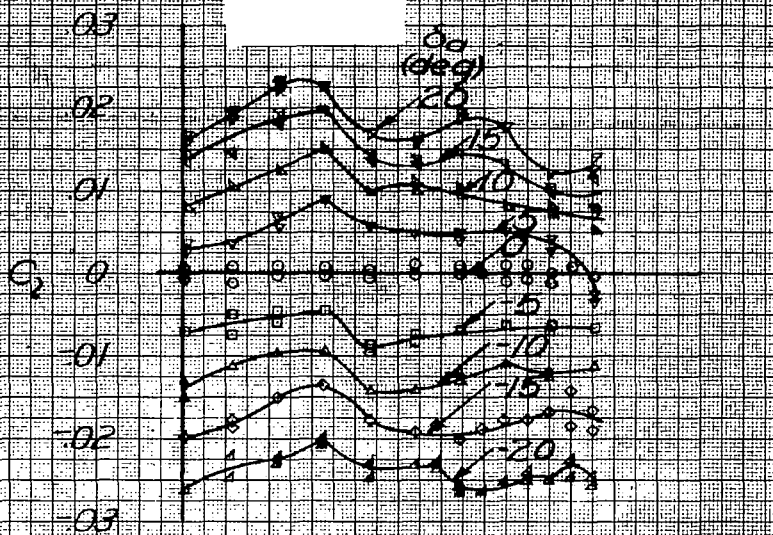
Figure 17.—Aileron characteristics of a 1/14-scale model of the XB-30 airplane. Wing W_2, $R \approx 4,500,000$, $M \approx 0.17$.
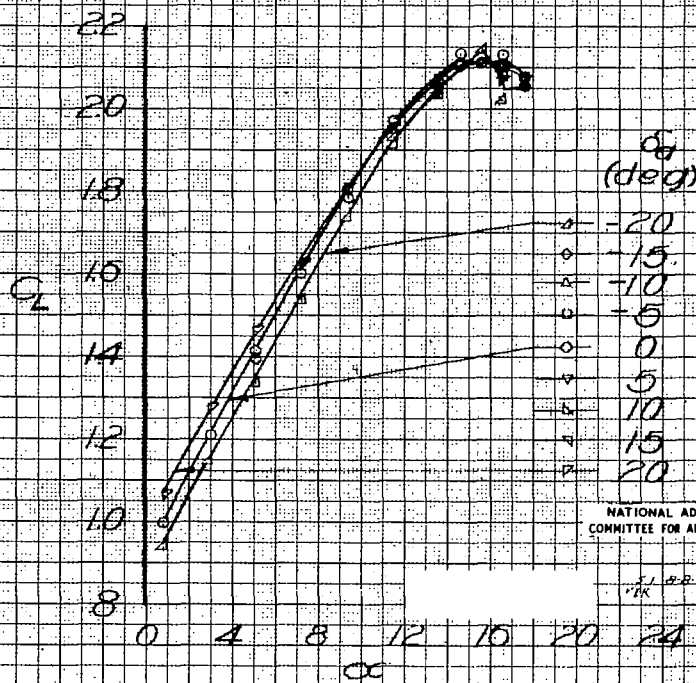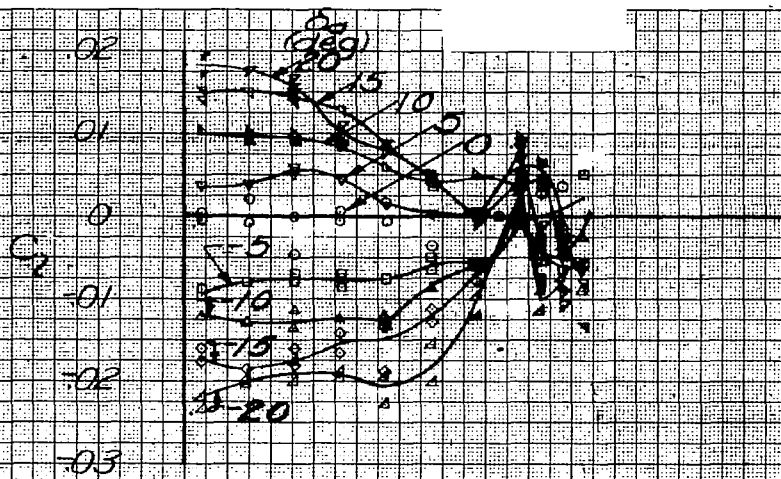
XB-30
191 PT

(b) $\delta_{f_i} = 40°$; $\delta_{f_o} = 50°$.

Figure 17.- Continued.
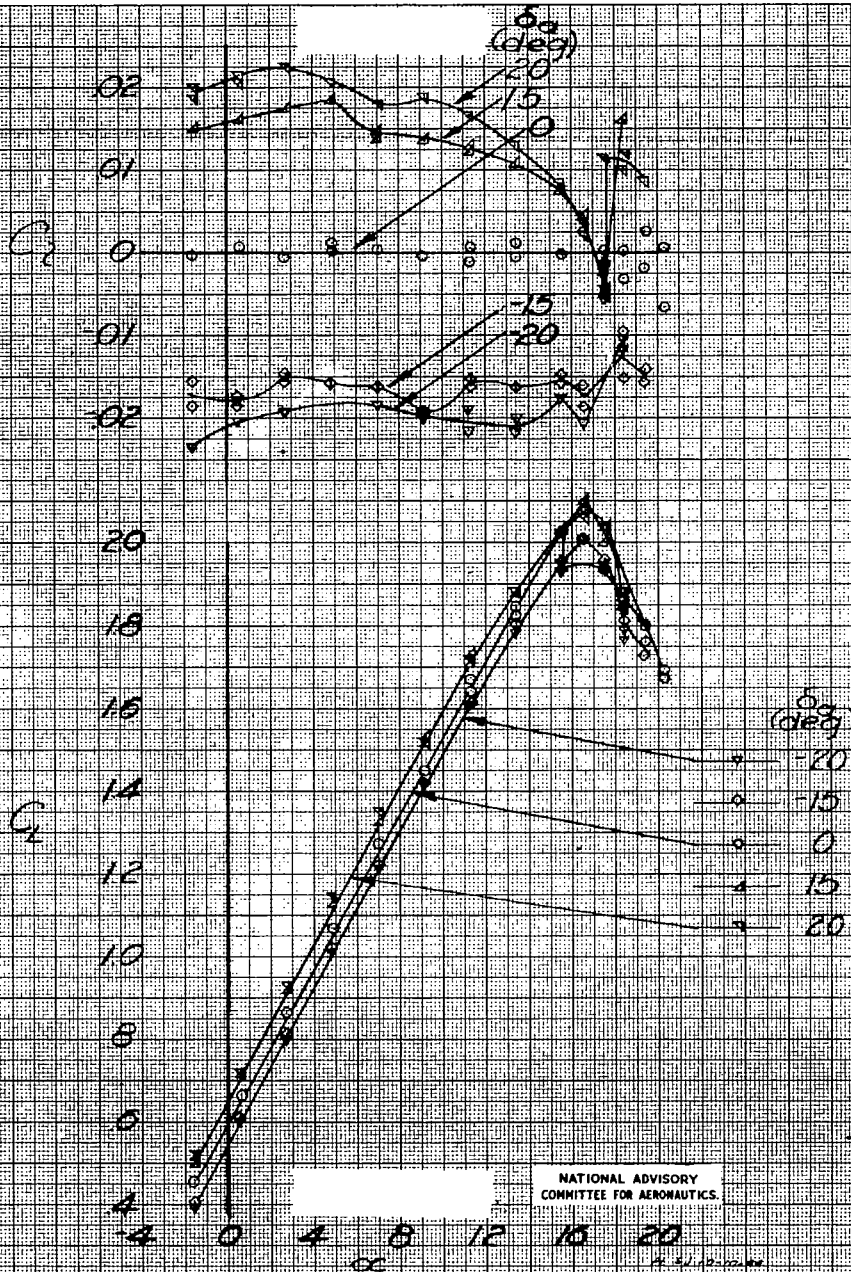
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XB-30
19-PT

δ_a (deg)

C_n

C_L

δ_a (deg)
- -20
- -15
- 0
- 15
- 20

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α

(c) $\delta_{f_i} = 40°$

Figure 17. - Continued.

XB-36
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(d) $\delta_{fs} = 50°$

Figure 17.- Concluded.

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191 PT

Figure 18.- Estimated helix angle for XB-36 airplane with wing W₂.

(b) $\delta_{f_s} = 50°$.

Figure 19.- Concluded.

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Figure 20.- Estimated helix angle for XB-36 airplane with wing W3.
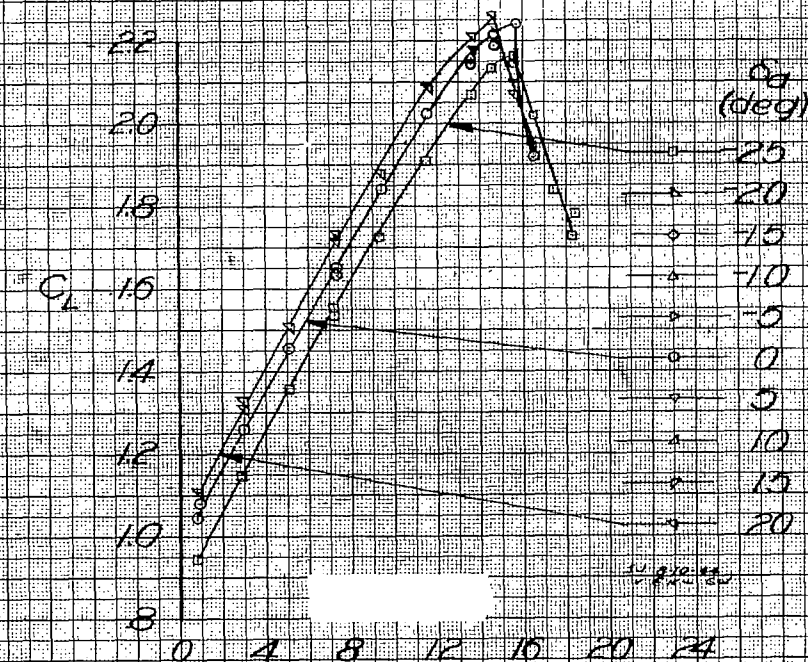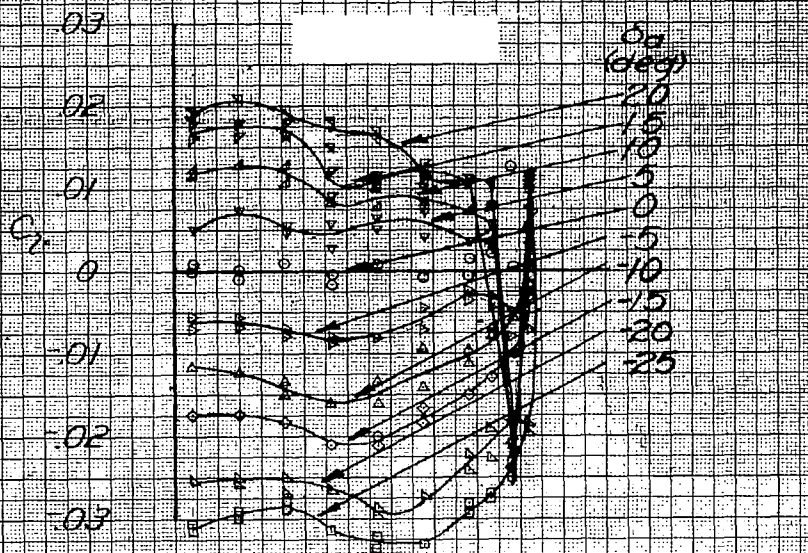
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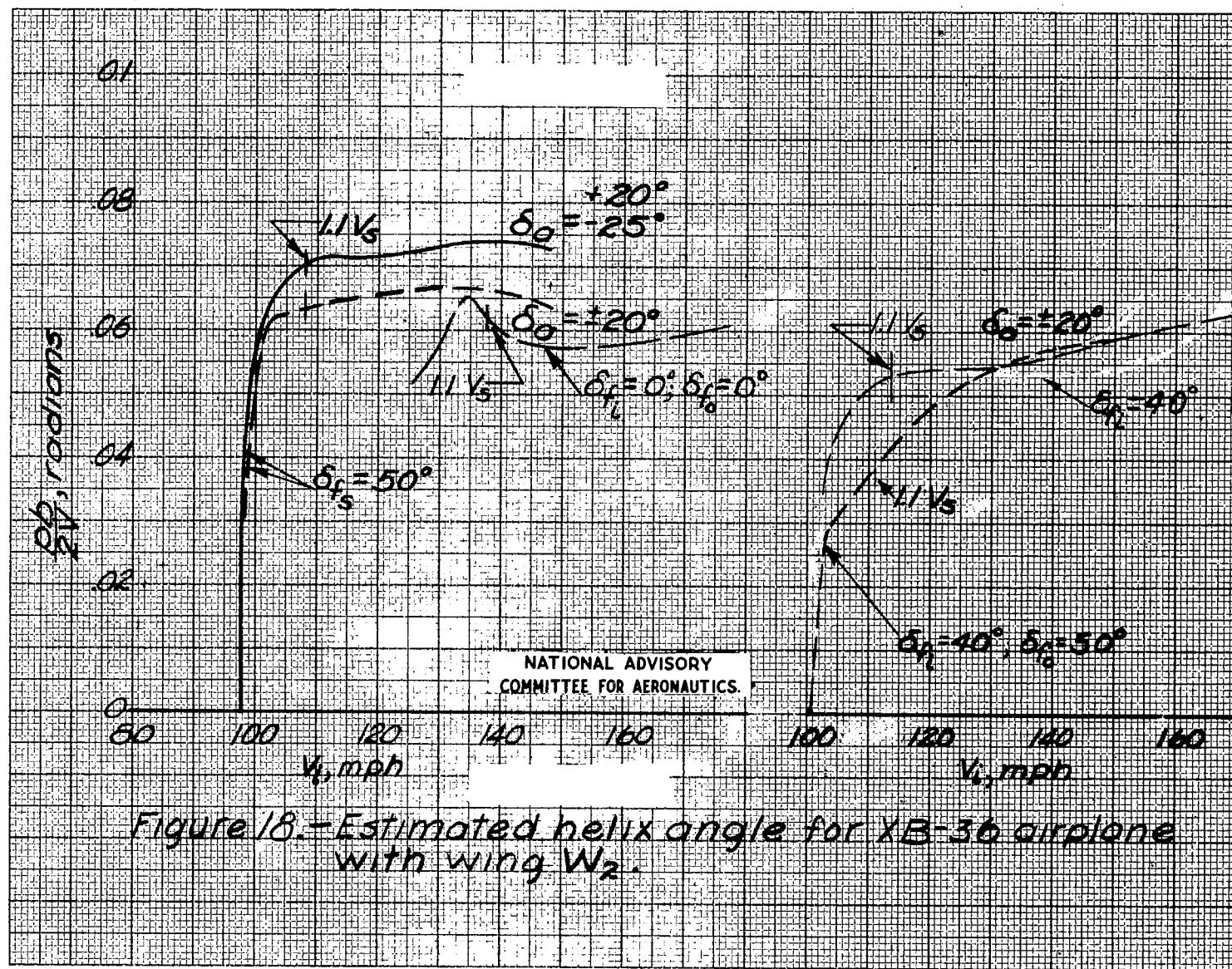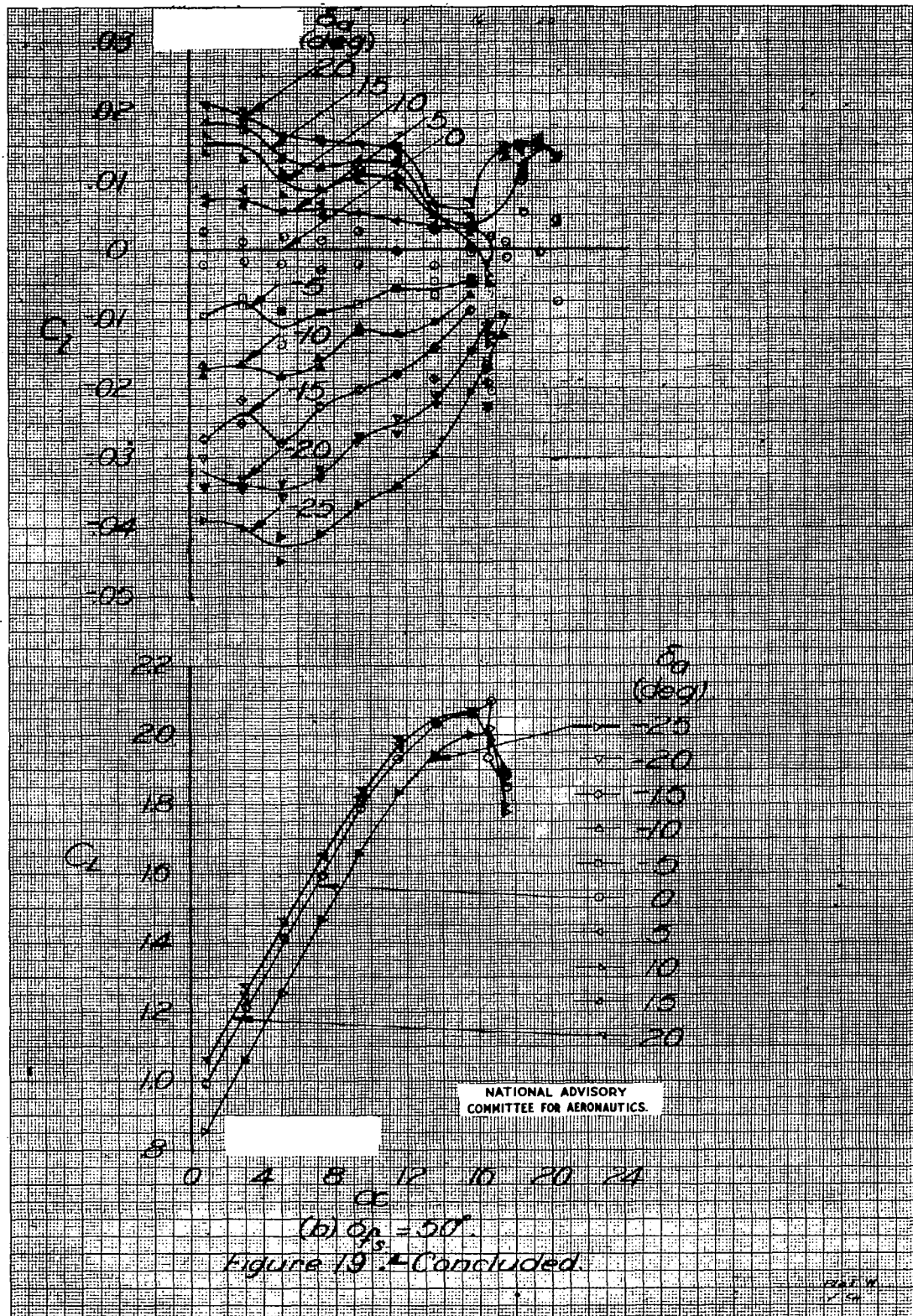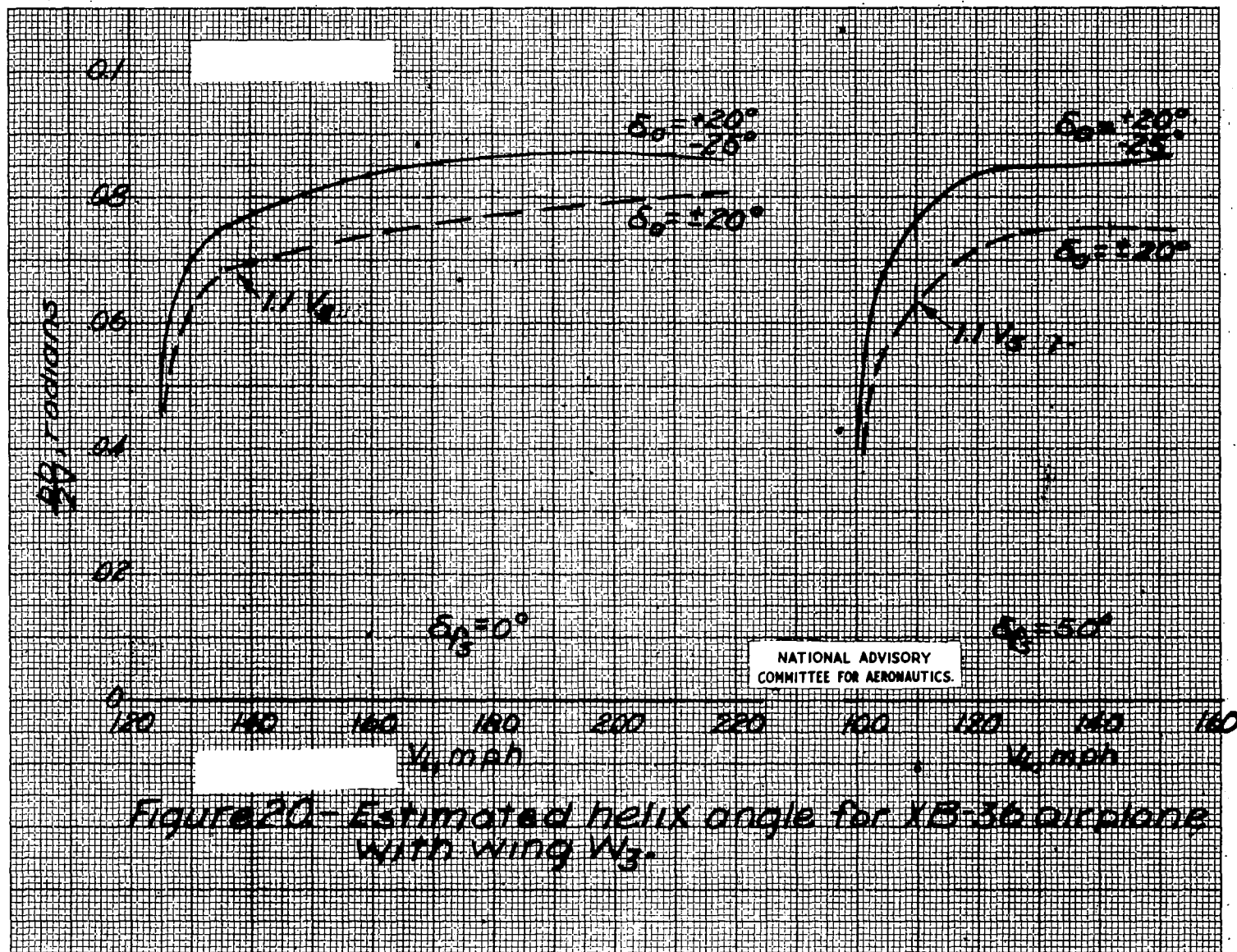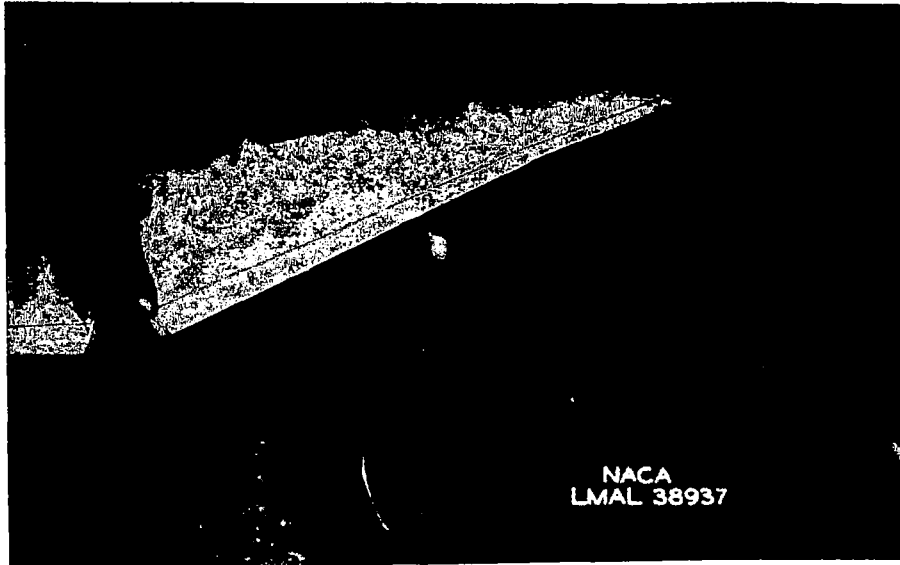
(a) Top view.
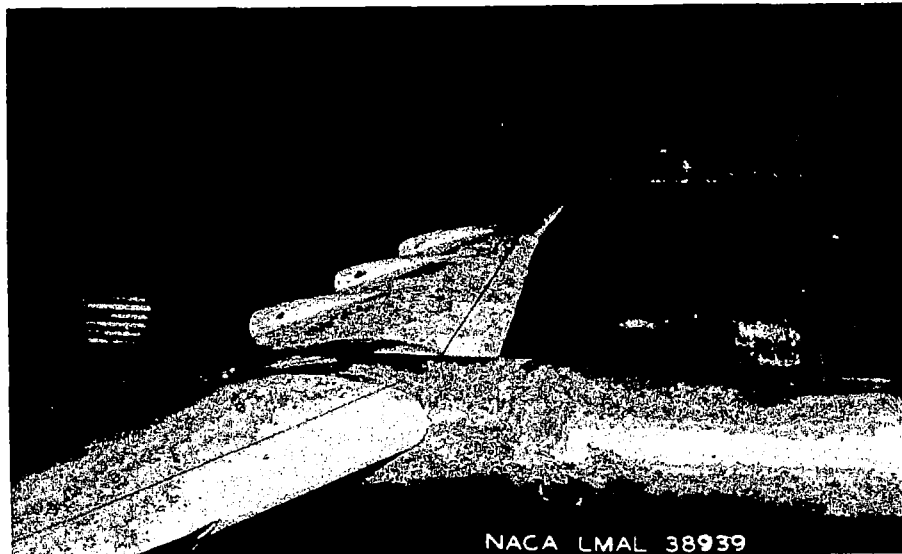
(b) Side view.

Figure 21.- Transition strip; $\frac{1}{14}$-scale model of the XB-36 airplane.
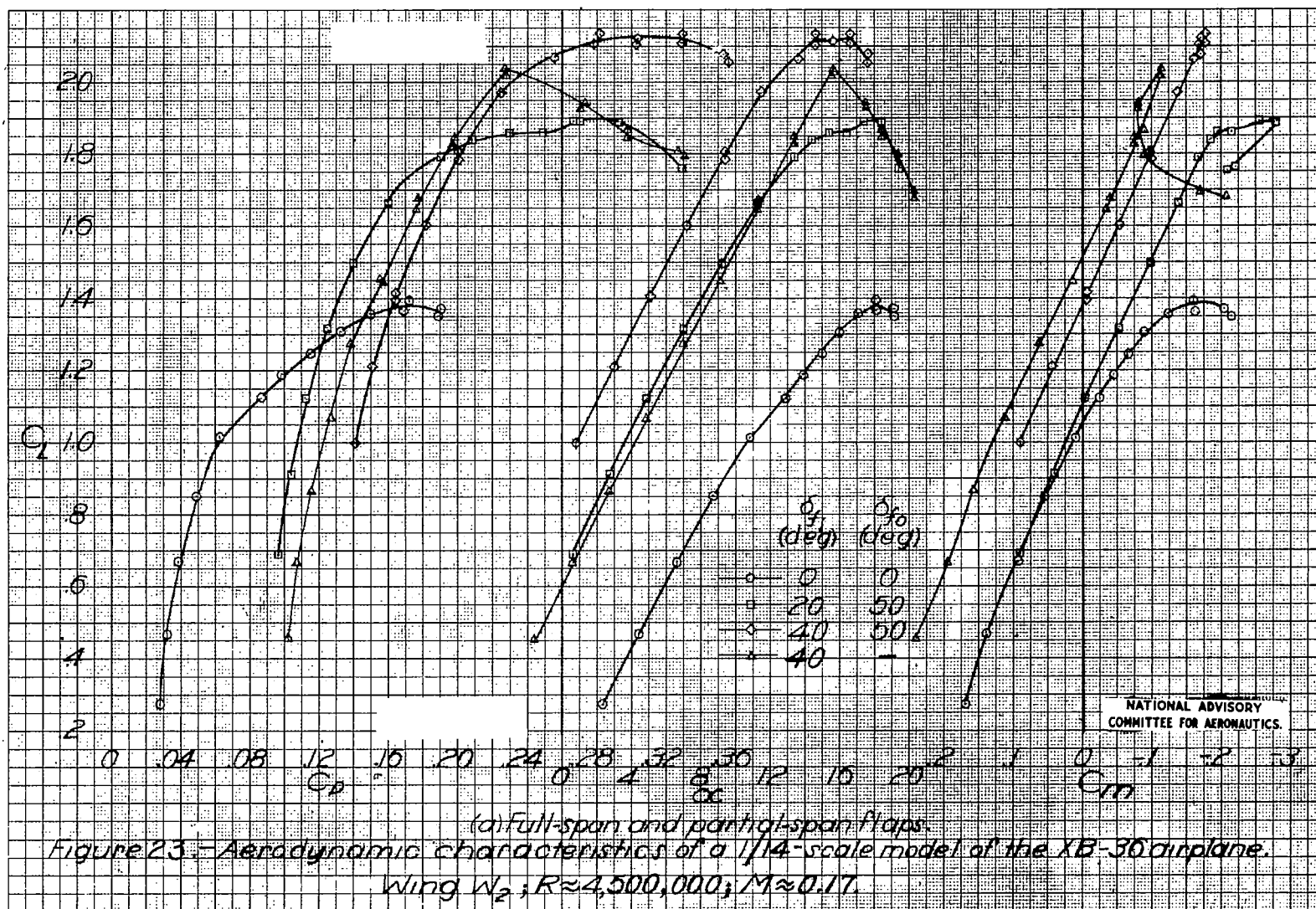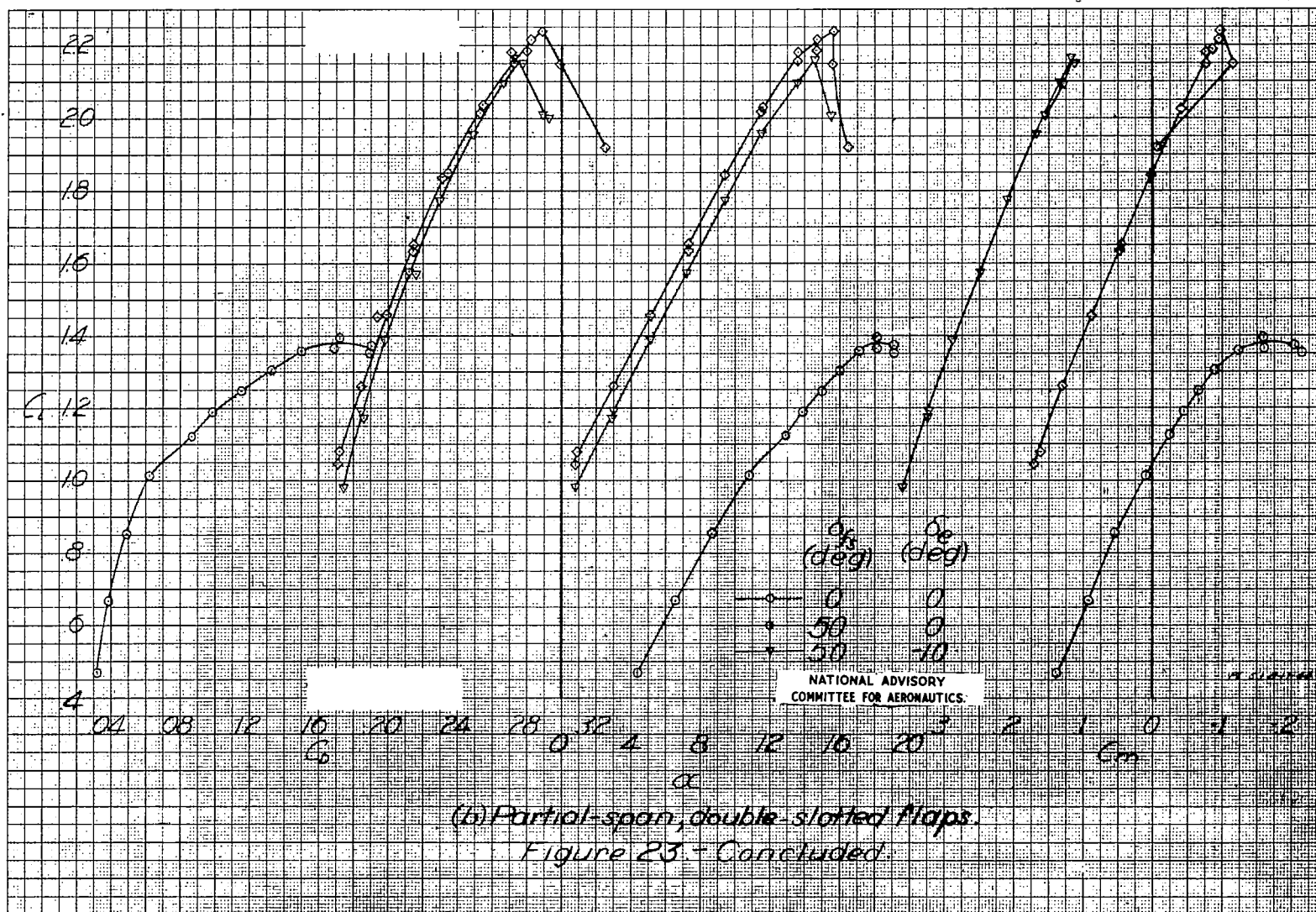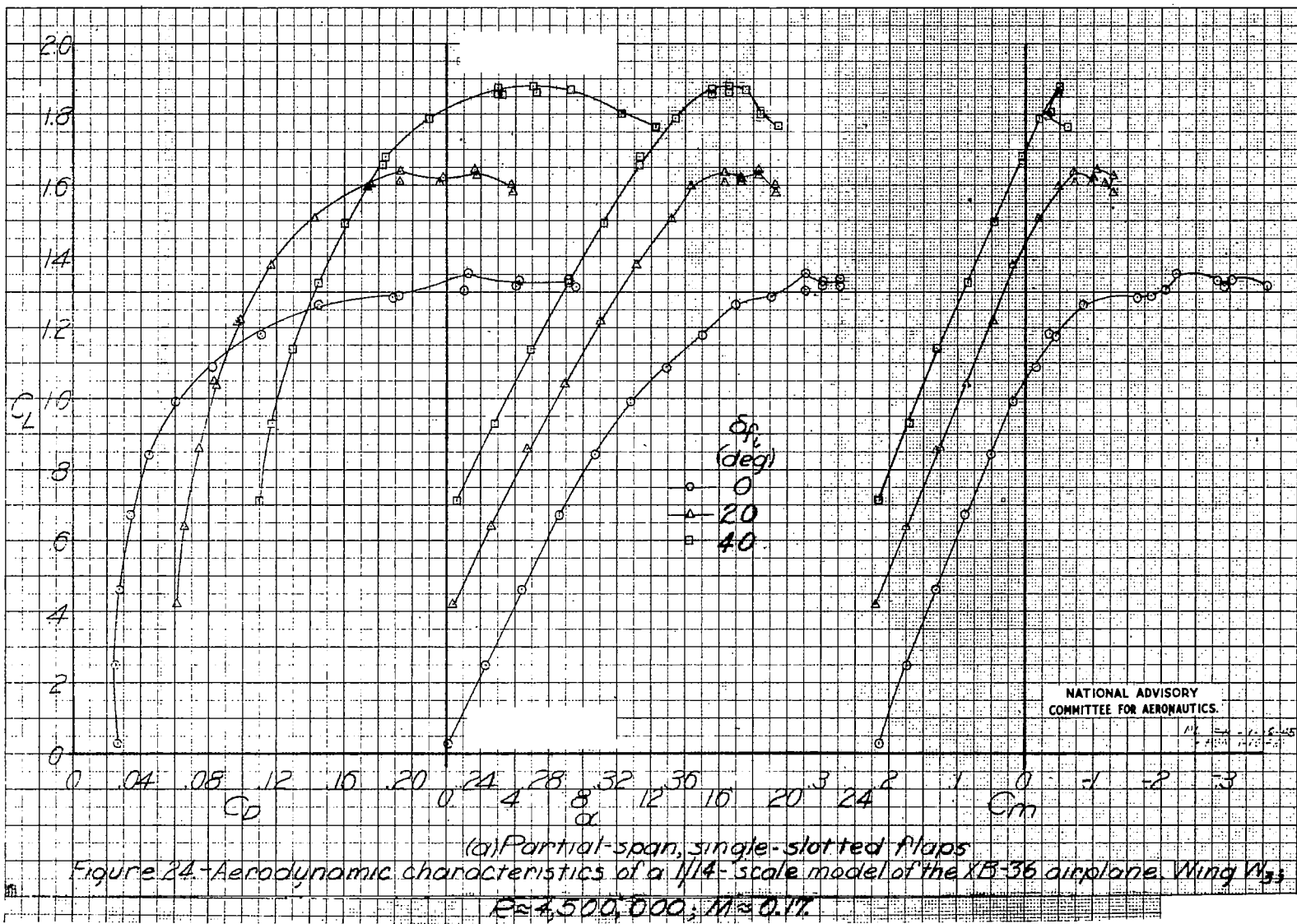
(a) Natural transition.
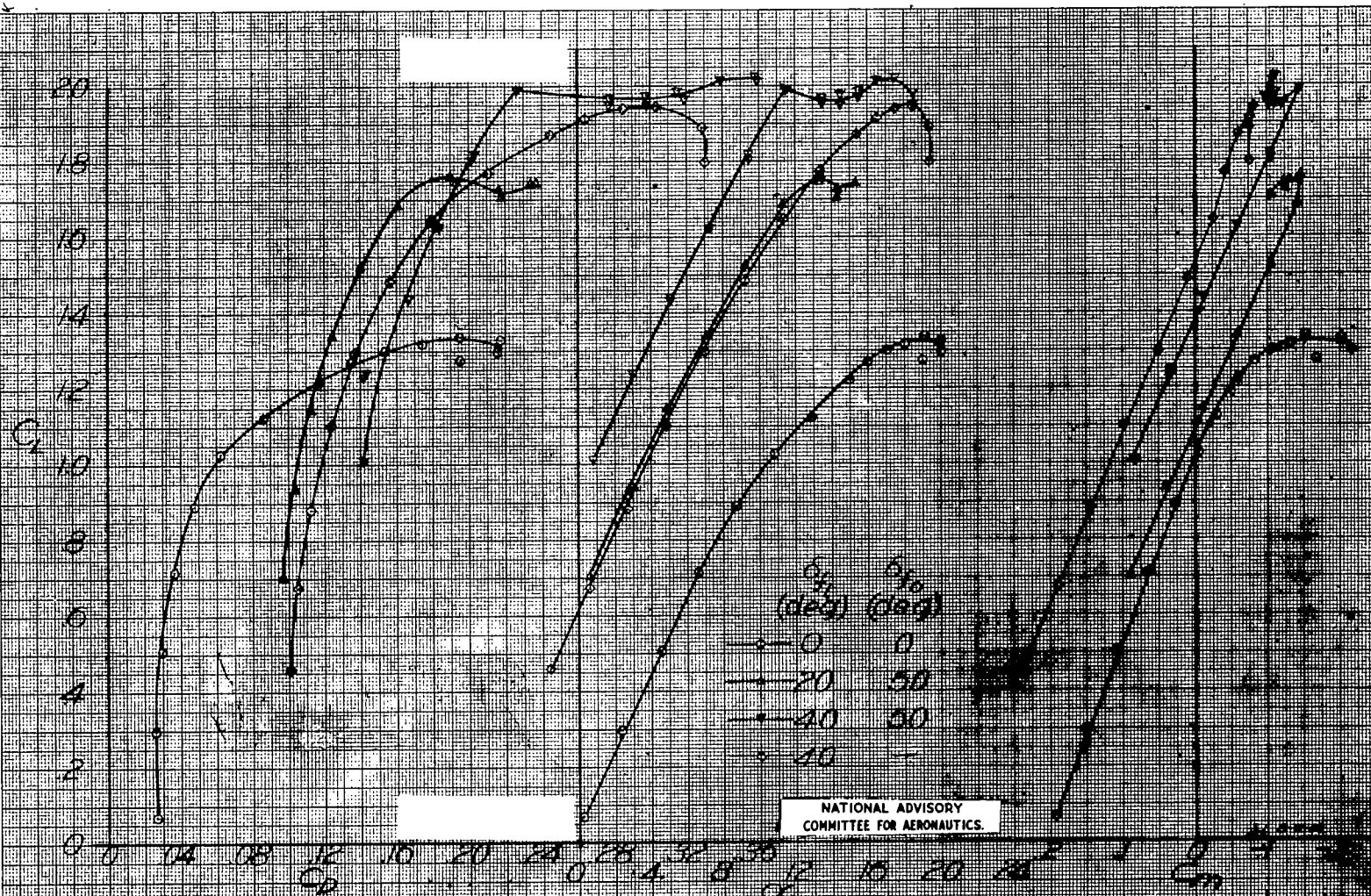
Figure 22. Aerodynamic characteristics of a 1/14-scale model of the XB-36 airplane. Wing W₁.
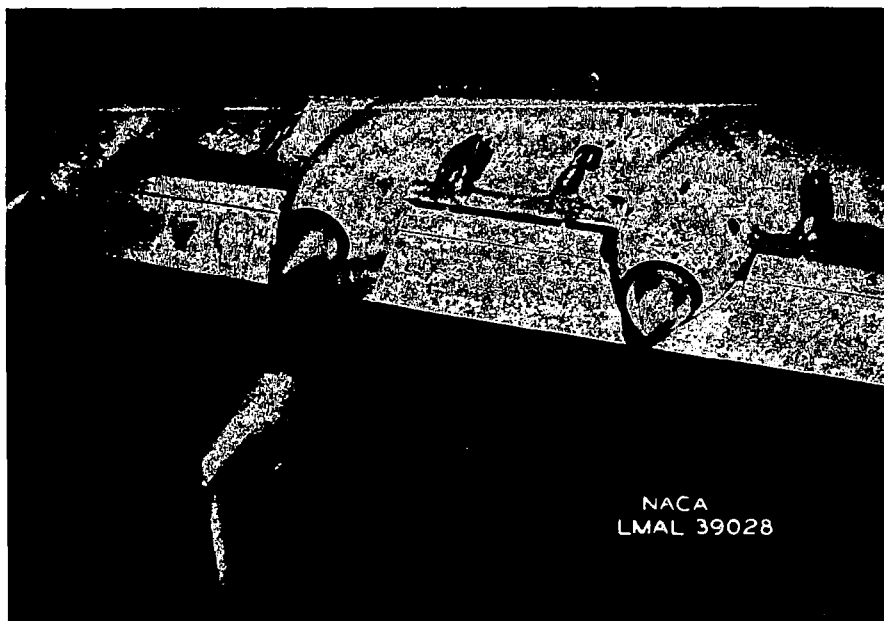R = 4,500,000; M = 0.17

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(b) Fixed transition.

Figure 22.- Concluded.

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(a) Full-span and partial-span flaps.

Figure 23.- Aerodynamic characteristics of a 1/14-scale model of the XB-36 airplane.
Wing W_2; $R \approx 4,500,000$; $M \approx 0.17$.

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δ_{fs} (deg) δ_{e} (deg)

0	0
50	0
50	-10

(b) Partial-span, double-slotted flaps.

Figure 23.- Concluded.

(a) Partial-span, single-slotted flaps

Figure 24.- Aerodynamic characteristics of a 1/14- scale model of the XB-36 airplane. Wing W_{33}

$R \approx 4,500,000$; $M \approx 0.17$.

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δ_f
(deg)
○ 0
△ 20
□ 40

(b) Partial-span, double-slotted flaps.
Figure 24.- Concluded.

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(a) Full seal.

(b) Modified seal.

Figure 25.- Flap-nacelle seals; $\frac{1}{14}$-scale model of the XB-36 airplane.
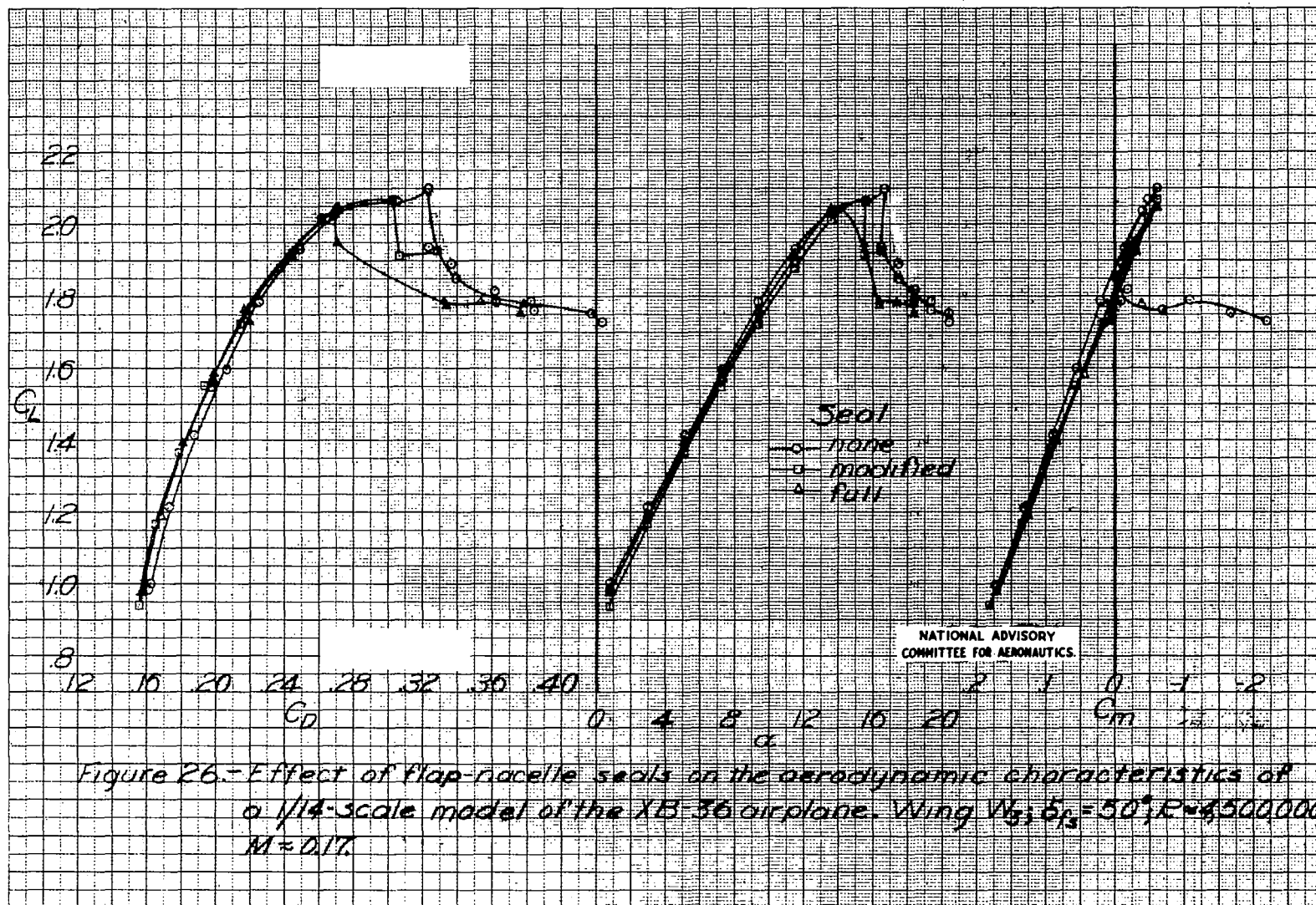
Figure 26.- Effect of flap-nacelle seals on the aerodynamic characteristics of a 1/14-scale model of the XB-36 airplane. Wing W_3; $\delta_{f_3} = 50°$; $R \approx 4,500,000$; $M \approx 0.17$.
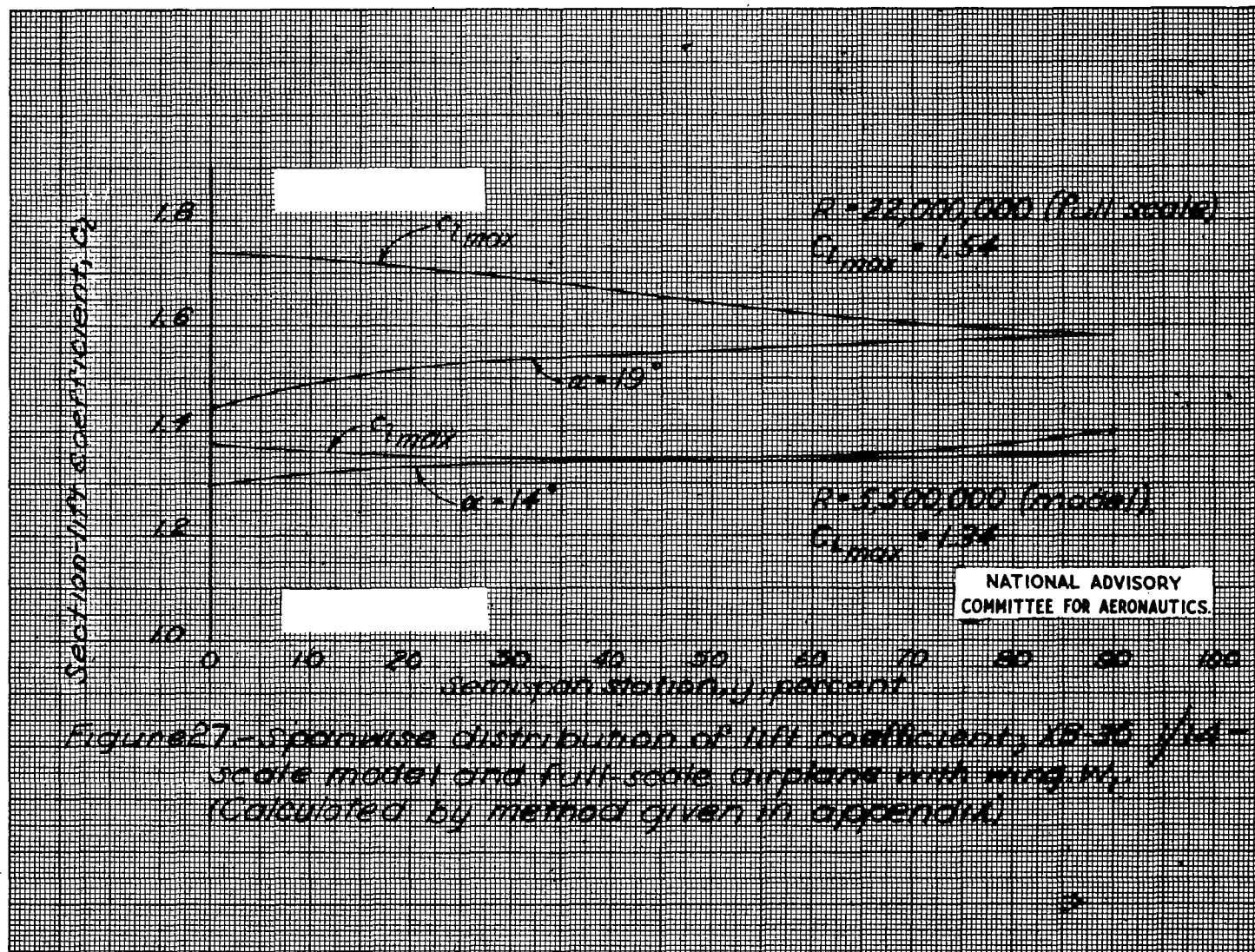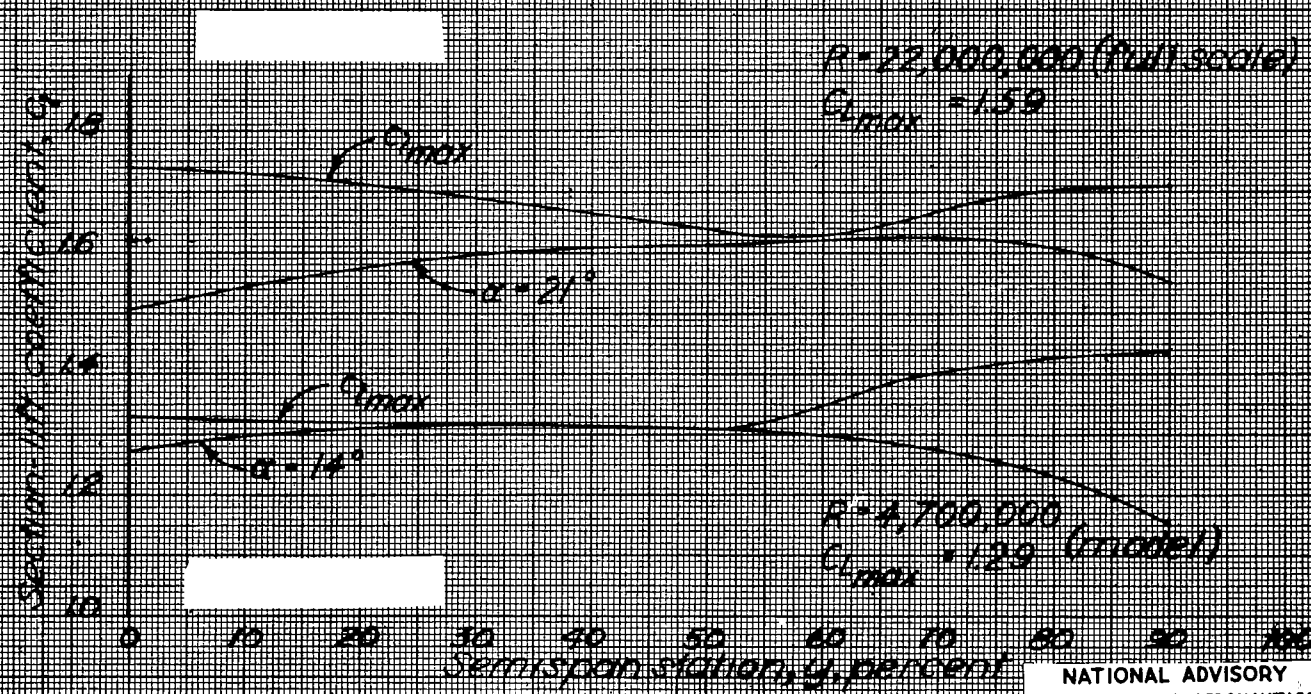
Figure 27.- Spanwise distribution of lift coefficient, 18.35 1/14 - scale model and full-scale airplane with wing W₁. (Calculated by method given in appendix.)

Figure 28.— Spanwise distribution of lift coefficient, XP-50 1/14-scale model and full-scale airplane with wing N_3. (Calculated by method given in appendix.)